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The Tree-Ring Dating of the Tower and Spire at Salisbury Cathedral, Wiltshire

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Summary

Thirty-three timbers were sampled from the tower and spire at Salisbury Cathedral during 1990, and a further 32 timbers sampled during 2003 and 2004. Four major elements were sampled and dated: the reset floor structure at the base of the clock chamber with felling dates of spring and summer AD 1242 were found, the Baltic oak ceiling boards to this floor structure with a felling date range of AD 1358-74, the spire scaffold with a felling date range of AD 1344-76, and the timber support tower in the bell chamber underneath the spire with a felling date range of AD 1687-1719. A number of thirteenth and seventeenth century reused timbers were also found in the timber support tower and spire scaffold itself.

The analysis resulted in four replicated site chronologies being produced: the 175-ring site master ***SARUM14*** spanning the years AD 1067-1241, the 238-ring site master ***SARUM15*** spanning the years AD 1117-1354, the 110-ring site master ***SARUM16*** spanning the years AD 1229-1338, and the 129-ring site master ***SARUM17*** spanning the years AD 1556-1684.

The dating of the spire scaffold to the third quarter of the fourteenth century is contrary to most established theories on architectural the development of the tower and spire. Whilst the architectural detailing of the decoration confirms that the tower and stone spire were constructed in the first quarter of the fourteenth century, detailed analysis of the structure and documentary material supports the conclusion that the spire scaffold was subsequently inserted within the spire half a century later. This was most probably to repair damage sustained by the top of the spire in AD 1362, and to give permanent internal access to the top of the spire and to give some tensile restraint to the capstone.

Keywords

Dendrochronology
Standing Buildings

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Salisbury Cathedral from the south-east. © Crown copyright. NMR. FF95/110

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Introduction:

Salisbury Cathedral is one of the country's finest ecclesiastical buildings, built principally during the mid-thirteenth century, but with one major later addition - the early fourteenth-century tower and spire (Figs 1 and 2). In addition to the exceptional quality of the stonework, Salisbury is noted for its outstanding timber roofs, a number of which survive largely unaltered. Since 1998 the Cathedral has been the subject of an ongoing phased programme of roof repairs grant-aided by English Heritage. As part of the associated archaeological recording of the timber fabric within the affected areas, English Heritage has commissioned a series of extensive dendrochronological surveys of the timberwork. The first area to be studied was the roofs over the Trinity, or eastern chapels, which was the first part of the cathedral to be completed. Felling dates of Spring AD 1222 accorded well with the documented dedication of these chapels in September AD 1225. The dendrochronology here revealed that the majority of the structural timber of these roofs was imported from the Dublin area of Ireland, lending credence to a sole documentary reference of timber being bought from William of Dublin (Miles 2002a).

The second phase of works commenced during 2000 to the north nave triforium and the north porch roof above the Parvis Chamber. Here felling dates of AD 1251/2 and AD 1254/5 were found from timbers of English origin, and a series of under-lead sarking boards at the west end of north nave triforium were discovered to have been imported, again from the south-east area of Ireland. Four well-replicated reference chronologies were created from these previous studies, two of English provenance and two from Ireland (Miles 2002b). Also studied were the two great doors at the west end of the nave as well as two associated doors to the Parvis Chamber and north nave triforium. The west end was presumed to be completed by AD 1266, if not by AD 1258, even though on stylistic grounds the niche statues were put in from the last decade of the thirteenth century (Ayres 2000). The results of the dating of the boards from the doors show that they are all primary thirteenth-century fabric; the west doors' material originating again from Ireland, whilst the majority of the other two were of English origin.

The present investigations cover the timber of the tower and spire (Figs 3, 4 and 5). This has been undertaken in several stages during the past decade. In advance of the RCHME book on Salisbury Cathedral (Cocke and Kidson 1993) Robert Howard and Gavin Simpson of Nottingham University were commissioned to undertake a programme of sampling the various timber elements within the tower and spire (Figs 6 and 7). A total of 33 samples were taken and positive results were achieved for the clock chamber floor in the lower stage of the tower. Dates were also obtained from the remnants of a boarded ceiling or vault to the soffits (underside) of the timbers of the floor and they were identified as being of Baltic origin. Although only tentative dates were found for the spire scaffold and timber support tower below, some reused primary-phase timbers were identified and dated (Howard 1991). A summary of the results for the clock chamber floor and applied boarding was published in *Vernacular Architecture* the same year (Howard *et al* 1991). The following year, results for the reused thirteenth-century timbers in the spire were published in the same journal (Howard *et al* 1992).

A decade later, as part of the extended programme of dendrochronology in the adjoining nave, north transept, and choir high roofs, further sampling was commissioned by English Heritage of the clock chamber floor structure and applied Baltic boarding. The purpose of this work was to enhance and refine the dating to these two elements. A further 20 samples were taken between these two phases with particular attention being made to retain complete sapwood where possible on the floor structure, and obtain more heartwood/sapwood boundaries on the Baltic oak boarding. Samples were also taken from the main floor beams, the wall posts, braces, and saddles. In addition, the data from 1990 was reviewed and compared against a much wider selection of reference chronologies than was available at the time, and some of the tentative dating was confirmed.

However, inconsistencies in felling date ranges in some of the material from 1990 highlighted the need for further sampling and a third group of twelve samples was taken in early 2004. This concentrated on the primary and reused timbers within the timber support tower in the top stage of the tower.

Description of the Tower and Spire:

The timber structures in the tower and spire have been most fully described by Hewett (1985, 141-5) and Tatton-Brown (1991, 1996). They were all examined by one of the authors (GS) as a preliminary to sampling for tree-ring dating in 1990. In the following section they are described according to the levels at which they occur, starting with the lowest.

I: The Tower Base

It has long been recognized that the first masonry structure over the central crossing of the cathedral was a squat tower or lantern rising no more than 10ft (3.05m) above the adjacent high roofs, perhaps with some kind of timber structure on top. When this part of the cathedral was encased in scaffolding in the 1990s for the conservation of the fabric, it was possible to examine the masonry closely. Through this study the original nature of the structure and its subsequent development became clearer and can now be related to the chronology which has been established from dendrochronology, documentary, and architectural sources.

The top course of the original masonry was found to have a series of lead plugs, a little over an inch in diameter, spaced at intervals of about 3ft (900mm), all around the exterior of the lantern (Fig 8a). Initially it was thought that these might indicate an iron framework run in with lead within the thickness of the wall, as is present at the top of the tower and base of the spire (Reeves *et al* 1992, figs 2 and 4, 384, 387-8). However, further investigation showed that they do not penetrate the masonry by more than an inch or two (*c* 50mm) and so they are best explained as the means of securing the edges of lead sheeting covering a timber structure rising from the masonry lantern. In this respect it was similar to the contemporary belfry or *campanile* which stood in the Close, north-west of the cathedral, until its final demolition in *c* AD 1790 (Cocke and Kidson 1993, pls 17, 18 and 34). This was a heavily buttressed square stone tower surmounted by a triple staged structure of timber covered with lead. The lowest stage was a square bell-chamber recessed behind masonry parapets but with its lower walls battered so that they sloped down to them on all sides. The second stage was an octagonal drum, which was topped by a short spire. A closer parallel might be the mid thirteenth-century bell-tower of St Mary's church, Long Sutton, Lincolnshire. This, like the Salisbury lantern, has stair turrets at each corner surmounted by little timber and lead spirelets, and an unrecessed timber-framed spire covered with lead which is fastened directly to the masonry at its base (Fig 9). A simple reconstruction of how Salisbury Cathedral might have looked at the end of the thirteenth century is shown in Figure 10. This arrangement is supported by the seal of Bishop Walter de la Wyle (AD 1263-71) which depicts, beneath his effigy, a building, presumable intended to represent the Cathedral, with a short central spire of this kind (Fig 11).

Internally, Salisbury's masonry lantern has an open arcade of four bays on each side with alternating piers and vertical shafts of Purbeck marble which takes up nearly two-thirds of its height. These fine arcaded passages, it must be assumed, were designed to be seen from the floor of the crossing, like those of the original, low thirteenth-century crossing tower of Lincoln Cathedral. At Salisbury, this space is floored over, obscuring the view from below. Comparison with the cross-section of the *campanile* in the Close show that its floors were of similar construction (Price 1753, pl 10), suggesting that this is original thirteenth-century fabric. Yet, if only judging from its position, it would seem unlikely to be part of the architect's original design, and other features contribute to this conclusion. The wall-posts of the brackets supporting the ends of the common joists are in slots cut out of the string course just below the arcading, and the bases of the piers have been cut back to provide a minimal bearing for the ends of the longitudinal bridging beams. Certainly neither of these awkward conflicts are consistent with the otherwise careful planning of the Cathedral.

It is possible that this present floor structure is the base of the original tower roof. When the spire and upper stages of the tower were constructed in the early fourteenth century, this would have necessitated the removal of the original roof structure of the lantern. Given that the inside width of the walls at the

top of the original thirteenth-century tower are the same as that at the base, it would be a logical and economical decision to simply dismantle the timber structure and lower it to a new position at the bottom of the tower. This would then provide a working and staging platform at the level of the major high roofs of the cathedral and would also protect its interior from the obvious disturbance resulting from such a major undertaking as raising the tower.

The floor consists of eight common joists measuring 11in by 12in (275mm x 300mm) spanning north-south and bearing on the ledge created by the arcade walkway. The joists are also supported on two east-west bridging beams spanning 32ft (9.75m) between the inner faces of the wall. These two beams are given additional support by brackets beneath the ends of the joists, the saddles of which have their inner ends tenoned into their sides (Fig 12). Each saddle has a carpenter's assembly mark, *I* to *XVI*, anti-clockwise from the south-west corner (Fig 7). The wall-posts were probably seated on corbels now incorporated in the later stone crossing-vault of AD 1479-80. The centre joist has been trimmed to form a square-framed aperture at the centre, presumably for hoisting bells in the original tower (Tatton-Brown 1991, fig 3).

One feature that may explain the apparently insensitive insertion of the floor in this position is that joists towards its corners show evidence of rubbing or grooving by bell-ropes. This is best seen in the north-east where a joist has been cut back and there are remains of a piece of leather nailed on to reduce abrasion. The similarity of the floor construction to those in the *campanile* has already been noted. In the thirteenth and fourteenth centuries in major Benedictine churches it was customary to ring bells in the crossing tower which were used primarily for participation in services and ritual from the floor of the church (Simpson 2001, 211). This was also the custom at Salisbury (Morgan 2003). It was therefore essential that they should be clearly heard and a position as low as possible over the crossing and absence of a vault or other obstruction beneath them would have facilitated that. Medieval documents concerning the processions and ceremonies in the cathedral relate that the altarists, whose duty it was to prepare the altar(s) for the priest(s) before the service(s), were also responsible for ringing the bells at the appointed times. They had to ensure that their ringing was synchronised, as was necessary, with whatever ritual or ceremony was in progress in the cathedral and particularly at the altars (Wordsworth 1901, 126, 128). Bells in an adjacent *campanile* had a wider audience and were rung, probably by other officials, on different occasions.

The floor was eventually hidden from view from below by a ceiling of cleft oak boards fitted together, side-by-side, with V-tongue and groove joints of medieval type and nailed to the soffits of the joists and braces of the brackets (Tatton-Brown 1991, fig 3). A square aperture was left at the centre of the floor, and also at each corner. The latter may have been rope-wells for bells. This ceiling was eventually removed by sawing out the boards, leaving stub-ends still attached to the joists and brackets (Fig 13), probably when the present lierne vault was inserted beneath in AD 1479-80 (Fig 14). The Fabric Accounts for this work are among few such Salisbury Cathedral documents to have survived from before the Reformation and record that 100 man-days were spent between the end of October and mid-December AD 1479 in 'breaking voltes'. The reference is presumably to the dismantling of the boarded ceiling, and may also indicate the provision of the access scaffolding, in preparation for the construction of the stone vault, the accounts for which immediately follow. By the second half of the fifteenth century the tradition of the frequent ringing of bells during processions and ceremonies in the cathedral seems to have been maintained only with difficulty. When Bishop Beauchamp made his visitation in January AD 1475 a complaint was made to him that the altarists were not fulfilling their duties as ringers 'so the sacristayns and theyr servaunts must pourvay vycarys and other estrangers to helpe theym.' The bishop was implored 'to compell the for seyd altaristers to kepe the costome & usage of ryngynge ..... upon a certayn payn, in worshyppe of God and your chyrche afore seyd.' It is therefore significant that there seems to be no provision in the new vault for the ringing of bells from the floor of the cathedral (Wordsworth 1901, 155-6).

II: The Tower

The original timber structure over the lantern was demolished, probably sometime in the early years of the fourteenth century. Work began on a new structure, perhaps a spire or lantern which was recessed behind stone parapets. One, or in places two, courses of these still survive, the lower course decorated with ball flowers and fleuron trails and with gutter-spouts at each corner to clear the rainwater (Fig 8b; Morris 1996, pl xiv b). The same motifs are later used, *c* AD 1327, in a similar context around the stone parapets and gutter-spouts of the Octagon at Ely Cathedral on a level with the base of the lead and timber lantern (Salzman 1952, 390). However, the dating of this development at Salisbury depends largely on decorative architectural features such as the ballflower and the mouldings used on associated buttresses. Ballflower seems to have originated in the south-west of England and the earliest dateable context for its use on a building is Wells Cathedral Chapter House constructed AD 1286-1306. It is later used in great profusion on the Salisbury tower and spire (Tatton-Brown 1991, fig 4). It has been suggested that Bishop Master Simon of Ghent (AD 1295-1315) was responsible for initiating the new work. His tomb in the cathedral is decorated with ballflowers linked by fleuron trails and the earliest buttresses at the base of the lantern have been assigned to the early fourteenth-century years of his episcopacy (Tatton-Brown 1995; Cocke and Kidson 1993, pl 13; Morris 1996, 54). The buttresses are the main diagonals at the corners of the lantern and others which create a cage around the crossing at clerestory level. The extent of this buttressing must indicate that the structure that Simon was contemplating was to be heavier than what had gone before. However, it is doubtful if the work was ever completed as he had intended.

Simon of Ghent was succeeded as bishop by his close friend and successor, as Chancellor, at Oxford University, Master Roger de (Mortival) Martival in AD 1315 (Edwards 1949, 338-40). He had been a canon in residence at Lincoln Cathedral since AD 1307, during which time he had had the opportunity to follow work in progress raising the crossing tower. On promotion to dean in AD 1310, he had the responsibility of capping the Lincoln tower with a massive spire of timber and lead, which at 250ft (76.2m) was nearly as tall as the tower itself. At Salisbury, it seems likely that Roger took the decision not to proceed with Simon of Ghent's project as planned, but to embark on a more ambitious one in which he incorporated the lowest course of his predecessor's work as a decorative feature. Above this there is a course of ashlar masonry and then three courses which continue the theme of a parapet featuring crenellation, all new-built purely as decoration (Fig 8c). The new tower, and the spire particularly, depends upon networks of bars and clamps of iron all run in with lead for the cohesion of the masonry (Fig 15; Reeves *et al* 1992, fig 5). Iron reinforcement bars were used to a limited extent in the first phase of the crossing tower at Lincoln, whilst iron clamps were used more profusely in the second phase there. It was possibly the successful use of the latter technique at Lincoln which gave Roger the confidence to build so audaciously at Salisbury. In addition Morris (1996, 55) has identified a second phase of buttressing around the tower and in the galleries which was probably built during Roger's episcopacy. The spire and the tower would have been completed by the time of his death in AD 1330.

In the tower there were originally three floors, the lowest of which was about level with the sills of the lower windows and entrances to the stair turrets. There is now a timber gallery at a slightly higher level around all sides of the tower. The former existence of a floor is now nowhere apparent, suggesting perhaps that, as with the floor of the lantern, the masons took little heed of the carpenters requirements to accommodate it. However, a floor here is testified by Christopher Wren who suspended a plumb-bob 'from ye floore where ye Spire begins to ye seconde floore belowe, which is something above ye ridge of ye Church. The distance between these floors was 78 foot' (23.8m) (Wren Society 1934, 23). It also seems to be shown in Price's cross-section of the tower and spire of AD 1738 (Fig 5; Price 1753, pl 6). At least the gallery is not shown, which first appears in a similar view by Britton dated AD 1815 (1836, pl 22).

The reason for the loss of the floor and its replacement by the gallery is implied by Price (1753, 60) and Dodsworth (1814, 175) who records that the upper part of the tower was struck by lightning in June AD 1741, setting fire to a brace inside (Table 1). It took quite a hold and sparks set fire to timber near the base of the spire and more 'fell down to the floor just above the roof'. Nevertheless, there is no sign of any burning on the masonry.

The ends of the bridging joists supporting the floor must have rested on the sills of the window openings and the common joists may have been supported off the string course below. The principal structural timbers of the gallery are all re-used and may have been part of the previous floor. The surrounding rails are new timber and features of their carpentry are consistent with a mid-eighteenth century date. It is well illustrated and described by Hewett (1985, 139-42) who seems to have thought it an original feature. Nevertheless, it is not at all clear why the masons did not make provision for the timber supports for the floor, yet managed to execute window-seats which could only have been used in conjunction with an adjacent floor.

Neither is the floor midway up the tower original. This was originally lower than the present floor, at a level with the sills of the doors into the stair turrets. Like the floors below it was probably supported on bridging joists, spanning 32ft (9.75m), the ends of which may have rested on the sills of the window openings. The present floor is constructed in this way, its two bridging joists raised on substantial blocks of masonry on the sills of the east and west windows. The common joists are supported on them and their ends rest on bricks filling the lower parts of the north and south window openings and in holes cut in the walls. The floor is therefore some 3ft (3.05m) higher than the original and there are wooden steps to give access from the stair turret doors (Tatton-Brown 1991, fig 3).

A timber tower 12ft (3.66m) square and 38ft (11.58m) high has its corner posts tenoned into the bridging joists of this floor (Figs 7 and 16). It was erected to underpin the timbers from which the scaffold in the spire rises. It is an unremarkable structure - just four corner posts and two levels of rails, mostly in box-hearted oak (ie converted from a whole tree so that the pith is at the centre of the timber), with diagonal braces of re-used timber across each side of the second stage (Fig 17). The carpenters' marks and empty mortices of the latter suggest that they were collar beams from a large roof (perhaps that of the nave) of the same type as the existing medieval one in the north-east transept. Each corner post is supported by two braces at its base which are tenoned into the ends of the joists in each of the tower windows. That in the south-west opening was charred by the fire in AD 1741 and has been repaired as stated by Price and Dodsworth (Fig 18). This brace and joist-end with the repair, like others bearing on the sills have been partly encapsulated into the masonry of mullions inserted to reinforce the window openings, probably by Scott (Tatton-Brown 1991, 83).

On the north side of the tower at this level are frames for four bells. They were built shortly after the demolition of the belfry in the Close by Wyatt for the date AD 1793 is scratched into their west end. Wren thought he detected evidence of earlier bell-frames in the tower in AD 1668 (Wren Society 1934, 22). The medieval clock, rebuilt with a pendulum, was also put here, perhaps using the bells.

The timber framing at the top of the tower is much more complex. This is due to the need to underpin the spire scaffold as well as to later attempts to provide additional support. Each corner post of the tower is brought to the right height to support the framework above by the addition of short extensions scarfed on with bridled joints, which were later reinforced with pairs of iron straps secured with nuts and bolts. There are two substantial east-west plates morticed onto the heads of the posts, and two others running north-south are trenched over them. At the middle of each plate there are short, squat posts, braced on either side and trenched through the jowled tops to underpin each of the two 35ft (10.67m) long cross-beams which carry the spire scaffold at approximately one-third and two-thirds along their lengths. The cross-beams, which are about 12in by 7in (305mm by 178mm) in cross-section, bear on the walls at the top of the tower and later, probably in the nineteenth century, further

support was provided by brackets seated in slots between the window heads on each side (Tatton-Brown 1991, 83).

The timber tower is shown in Price's cross-section of the tower and spire dated AD 1738. He vaguely attributes the construction of both the tower and the floor on which it stands to sometime 'within the last century' (Fig 5). Dodsworth (1814, 176) assigns it to the early years of the eighteenth century. It is likely that its construction is related to a comprehensive report on the state of the fabric, giving proposals and estimates by Thomas Naish, the clerk of the works, in AD 1691. He proposed two new floors and general timber repairs in the tower at an estimated cost of £250 (Cocke and Kidson 1993, 22). The work he proposed on the masonry of the spire was given greater urgency by a lightning strike in December AD 1695 which inflicted considerable damage, the repair of which may have delayed completion of the work within the tower to the early years of the eighteenth century (Table 1).

III: The Spire

The Salisbury spire, rising to 404ft (123.14m) above the ground floor level, was, and still is, the tallest masonry structure in Britain. However, two other medieval buildings, old St Paul's in London and Lincoln Cathedral, both had contemporary timber spires which surpassed the Salisbury spire in height. Various estimates of the overall heights of these varied considerably, for instance old St Paul's was reckoned to not exceed 520ft (158.5m) in height (Dugdale 1658, 16), whilst a more conservative estimate placed it at 449ft (136.86m) (Hearsey 1961, 91). Estimates for the height of Lincoln also varied wildly, one source placing it at 524ft (159.72m) (Hearsey 1961, 99) whereas another source considered St Paul's to be the higher (Bonney 1891, 82). But despite differing opinions as to overall heights, the Lincoln spire was destroyed by a storm in AD 1548 (Bonney 1891, 82), and St Paul's was destroyed by fire, possibly by a lightening strike, shortly afterwards in AD 1561 (Hearsey 1961, 132). Nevertheless, the Salisbury spire is entirely constructed of stone, whereas both Lincoln and St Paul's spires were constructed of lead-covered timber. Thus, the stone construction of the Salisbury spire has proved it to be an exceptional structure which has endured for almost 700 years.

The spire itself is an octagonal stone shell 180ft (54.86m) high with a base of about 33ft (10.06m) wide internally. At the bottom the walls of the spire are about 2ft (610mm) thick but 20ft (6.1m) from the base they reduce to about 9in (229mm) (Fig 6). There is no internal support structure. Thus, when viewed from below, the interior of the spire would have the appearance of a hollow cone. The exterior is decorated with extensive ballflower on its angles, and there are three decorative bands of panels enclosing lozenges, quatrefoils, etc., which are the only relief to the otherwise flat cants to the spire itself (Fig 4). The interior is unlit apart from a series of small port-holes, now glazed, within the frieze bands, made in AD 1762.

The spire has long given cause for concern, both in relation to storm damage as well as long-term maintenance. Christopher Wren stated in his AD 1668 survey of the cathedral: 'There are other decayes in ye Spire and the higher you goe the more, some of which are the effects of ye sinking and declining of ye whole from ye Foundation, others are the effects of tempests that have shaken it, especially those which are toward the Top are of this nature from both causes' (Wren Society 1934, 24). Setting aside the fundamental structural weaknesses of the tower and spire first recorded in detail by Wren, the weather, for various reasons, presents the greatest threat.

The leaning of the top of the spire to the south-west recorded by Wren and Naish in the seventeenth century is probably largely due to greater compression on the many horizontal joints on its weather side as well as differential settlement and distortions in the crossing piers. This phenomenon is very common in tall, thin, structures built in lime mortar. It is most apparent in chimney stacks but there are many instances in church spires, the church of St Martin in Salisbury being the nearest example. The exposure of the masonry to the prevailing elements seems to result in a gradual leaching out of the

mortar due to its sand content having too much fine, silty material, ie weak tensile strength of mortar in masonry joints (Heyman 1967, 243). This results in a subsequent fractional settlement under load and a gradual curvature of the structure (J A Reeves, *pers comm*). However, this process would have been mitigated to some extent in the Salisbury spire by the horizontal and vertical clamps which join all the masonry blocks (Tatton-Brown 1996, fig 2, 61).

Their use may imply some awareness of such long-term problems by the medieval architect. However, wind and lightning can be much more sudden and devastating in their effects. The tower and spire are particularly vulnerable to lightning for which there are several documentary records of strikes over the centuries which caused severe damage (Table 1). It is likely that there were also less devastating incidents which went unrecorded. It is possible that the apex of the spire was repaired, or was even rebuilt before the last occasion, when nearly 30ft (9.15m) was replaced, in 1950. Certainly it was realised that it required regular attention and for this reason there is a small weather door, or access hatch, about 20ft (6.1m) below the base of the finial. This provided access for steeplejacks to the exterior and Price also describes the holes in the masonry just below this door for temporary scaffolding up the outside (Price 1753, pls 9, 17; Tatton-Brown 1996, 62-3). When the sub-dean, the Reverend Thomas Naish, son of the clerk of the works of the same name, went up the spire in July AD 1696 to view the damage done the previous winter he recorded in his diary 'I went out upon the scaffolds' - probably at this level (Slatter 1965). It was probably about this time that the capstone was strengthened with a series of iron ties and enclosed in a cradle of iron, as shown in the engraving of AD 1746 by Price (Fig 19). When further work was undertaken there in AD 1762 a cavity was found on the south side of the capstone containing a wooden box in a lead casket. It contained a piece of finely woven cloth. The cloth was said to be part of the Virgin's shroud (Dodsworth 1814, 176-7; Spring 1987, 58). No matter what, it must have been regarded as a holy relic and have been placed there to protect the cathedral from harm - an early form of spiritual lightning conductor. A similar container was placed at the top of a new spire of timber and lead on old St Paul's Cathedral, London in AD 1315 'in order that ... the relics might protect it from danger of storms' and the corners of the tower were reinforced with flying buttresses. Unfortunately these precautions were to no avail for a lightning strike damaged the spire in AD 1341 and in AD 1444 another strike caused a fire which broke out 'in the midst of the shaft' (Salzman 1952, 389, 391-2; Cook 1955, 32, 42).

About 30ft (9.15m) below the top of the spire the mast is suspended from an iron spindle which passed through the capstone and was attached to the base of an iron cross above (Figs 6 and 19). This section of the mast was repaired in AD 1738 and replaced in 1950 (Anon. 24-5; Tatton-Brown 1991). The weathervane, now in the north choir aisle, has a date of AD 1762 on it.

IV: The Spire Scaffold

General Remarks

There has been some debate as to whether the timber scaffold inside the spire was used in the construction of the spire, or is a later introduction. Both Hewett (1985) and Tatton-Brown (1996) considered the spire scaffold to be the same date as the spire itself, whilst another opinion saw the scaffold as a later fourteenth-century insertion to facilitate repairs resulting from the great storm of AD 1362 (Simpson 1996).

The bottom of the scaffold is at Eight Doors level, where access to the parapet walk is gained. At this level is the great wheel which was used to hoist materials up through the tower (Fig 20). This was last replaced in AD 1762 (Tatton-Brown 1996).

The scaffold has nine stages (Fig 6). The three lowest comprise a timber tower, much like that described in the top stage of the stone tower, but having in addition a central mast (Figs 21 and 22). Its

four corner posts and the mast are tenoned into the tops of the two cross-beams which support it below floor level (see timber support tower described above, Fig 7). For this reason the scaffold is twisted round so that its corners are at the cardinal points and its sides are not parallel with the later timber tower beneath.

The scaffold is almost entirely constructed of oak and much of the original or early, inserted timber is boxed-heart and selected from fast grown, immature trees. The tree-rings generally tend to be wide and few in number, which gives the timber greater strength since wide rings have a higher proportion of small, dense, latewood cells. The general impression given otherwise is of a lack of uniformity, both in the carpentry and in the quality of the timber. Although its design is undoubtedly much as originally conceived it is clearly not now a single period structure. There are repairs and additions in both green and re-used timber. Joints are held by pegs or wedges or a variety of metal fittings (spikes, nails, straps, stirrups, forelock and screw-thread bolts, and hooks and eyes). Timbers having the same function and at the same level or stage in the structure may be secured by different means, or have different forms of chamfer stop. Neither the central post or the four corner posts at the base of the tower are continuous with those of the second stage.

Stages 1 and 2: the original structure and its relationship to the spire
A careful survey of the structure has indicated that timbers with pegged joints were nearly always primary and where associated with carpenter's assembly marks were always so (Tatton-Brown 1996, fig 3). These marks are Roman numerals clockwise from I at the east corner to IV at the north corner with tags to identify different levels. On the basis of these criteria the west corner seems to have more original timber surviving than elsewhere. At Stage 1, the four corner posts, the angle struts between the corner posts and the ends of the cross beams with spiked chase-tenons, the central mast and two or three of the rails are original. Two of the struts at the base of the central mast are re-used timbers with carpenters' assembly marks of the kind used in the original roof of the north-east transept. The angle struts at the corner posts are among the most substantial of the original timbers and were the only ones to yield tree-ring dates.

At the top of Stage 1 the corner posts are tenoned into short sole plates which carry two rails secured by slip tenons. Two other rails at right angles to the former are halved across them and are supported from the posts by knee-braces secured by spikes. The corner posts of Stage 2 of the scaffold are tenoned into the intersection of the rails which all extend beyond the posts but stop short of the masonry. These shortcomings are made good by the addition of pieces of timber of the required length, joined with splayed and tabled scarf joints with bridled abutments, edge pegged, and with associated assembly marks (Fig 23; Hewett 1985, fig 233, 213; Tatton-Brown 1996, fig 2, bottom right). The joints have been reinforced by iron straps nailed around them which are probably original. With these extensions the rails now abut the masonry of the spire in each of its angles at the level where its inner face changes from vertical to inclined. The manner of this transition differs on the four sides of the spire octagon over the squinch arches (which cut off the corners of the tower and give access to the stair turrets) as compared with the other four sides between. At the latter the rising inclined face is set back about 6in (150mm) from the vertical face so that there is a ledge, which the uniformity of the tooling of the masonry above and below shows to be an original feature. On the other sides, however, there is no ledge but instead a course of masonry with an 18in (450mm) batter. Again this appears to be an original feature and one which prevented the carpenters from setting the ends of the extended rails squarely into the angles. The batter had therefore been cut back at either end to extend the ledges in order that they might be so placed (Fig 24). Had the rails been of a single piece they would have been too long to fit so tightly between opposite angles of the spire once its building above this level had been completed. The extension of the timbers by scarfing allowed this to be done, and the cutting back of the masonry to allow their placing demonstrates that this is what must have been done. The architectural evidence indicates therefore that the spire scaffold was not begun nor even contemplated until at least sometime after the construction of the spire had begun.

The Upper Stages

Pegged joints with associated assembly marks occur up to and including the third stage, but by the top of this stage the numbering system according to the corners seems to give way to one according to the level or stage and the marks are scratched, rather than grooved lines, as originally used below.

From Stages 5 to 9 inclusive, the tower-frame is replaced by successive groups of timbers radiating from the central mast. At each stage eight horizontal radii are held in place, like the spokes of an umbrella, by eight struts from the central mast below. The inner ends of these timbers have pierced iron straps which fit over iron hooks held in place by eight blocks spiked to the central mast and arranged segmentally around it in the form of a capital. The struts rest in the angles of the spire. They are slightly wider at their upper ends and each of the narrower horizontal timbers threads through a slot there and is secured by a wedge. No original assembly marks have been noted at these levels. The quality of the timber, however, does not much differ from lower levels. Re-used timber still occurs as, for example, horizontal cross-ties between the corners of the tower frame at Stage 3 and diagonal struts between the same corners and the mast at Stage 4. They are collar beams, probably from the south-east transept, or a roof of similar size and type.

Objectives of Dating:

The objectives for the tree-ring dating in 1992 was to allow a chronology of the spire to be determined through independent scientific means in advance of the 1993 RCHME publication *Salisbury Cathedral: Perspectives on the Architectural History*. Despite a variety of documentary sources, the various elements of the tower and spire posed a number of questions. Among the specific objectives of the dendrochronology was:

- to determine whether the floor of the clock chamber at the base of the tower was original thirteenth-century timberwork and if so, was it *in situ*.
- to determine whether the boarding fixed to the underside of the clock chamber floor was contemporary with it and if not, when was it inserted.
- to date when the timber support tower and floor structure the top of the tower was inserted.
- to date the spire scaffold to determine if it was constructed at the same time as the spire, or if it was inserted after the spire was built.
- to date some of the reused timbers in the timber support tower and spire scaffold and to try to relate them to other known building phases in the cathedral.
- to produce further replicated tree-ring chronologies for the cathedral and for the county of Wiltshire or further afield, including possibly the Baltic region or Ireland
- to try to obtain more precise felling dates, in order to correlate the documentary sources with the surviving timberwork.

Whilst the initial results of the 1992 dendrochronological survey by Robert Howard and Gavin Simpson dated a number of timbers from the clock chamber floor, none of the samples retained complete sapwood, giving a felling date range of AD 1236-71. The boarding below also dated well, and again the lack of sapwood could only give a felling date range of AD 1365-92. The dendrochronology also revealed that this boarding was of Baltic origin (Howard *et al* 1991). Regrettably, the dating failed conclusively to date the timber support tower and the spire scaffold above, and although a number of tentative dates were found for these elements, the matching was not sufficiently conclusive to allow any dates to be published. Nevertheless, a number of reused thirteenth-century timbers were identified in both the timber support tower and spire scaffold.

During the current works to the cathedral roofs, the opportunity was taken to take additional samples from the lower stage of the tower adjacent to the areas being re-roofed. The objectives of this second programme of work during 2003 were to enhance the 1992 results by tightening the felling date ranges and to try to provenance the material if felling dates were obtained. As part of this work, the 1992 material was reviewed. Fortunately, the number of available reference chronologies for the region had increased ten-fold during the intervening decade, allowing some of the tentative dates to be confirmed, and other undated samples to be dated. However, there were some inconsistencies and the felling date ranges of samples from the timber support tower proved unresolvable without further sampling.

Given this problem with some of the 1992 material, it was decided that further samples were required from the timber support tower to give the best coverage of the structure, and to allow precise felling dates to be obtained, and any phasing clearly identified. Therefore, a third limited programme of sampling in the timber tower was undertaken during January 2004 to resolve these problems.

Assessment:

The floor of the clock chamber was found to be variable in its suitability for dendrochronology. Most of the main joists were boxed-heart timbers, and despite their large size, many had fairly wide rings, indicating ring sequences of between 50 and 75 rings. The two main bridging beams were made from nearly boxed-heart timbers which were slow-grown, and thought to average between 75 and 125 rings. The smaller timbers such as the wall-posts, braces, and saddles were again converted from timbers of varying quality. Some of the braces were from large slow-grown trees which had been quartered or halved, having between 100 and 150 rings, whilst others were converted from fast-grown, boxed-heart timbers with less than 40 rings, making them totally unsuitable for dendrochronology. Very little sapwood survived on any of the timbers, and it was mostly on the faster-grown timbers, and in a poor state of preservation.

The floor had short lengths of V-edged oak boarding nailed to the soffits of the bridging beams and joists, and to the cheeks and soffits of the braces below. These boards had presumably been mostly sawn out late in AD 1479 to allow the insertion of the stone vault below. Virtually all of the boards were riven, and were from slow-grown oak, having an average of between 100 and 200 rings. They were clearly excellent material for tree-ring analysis. Although no sapwood survived, some retained clear heartwood/sapwood boundaries.

Whereas these floor beams and the boards were easily accessible from the stone vaults immediately below, the gallery and ceiling to the clock chamber above were impossible to sample without scaffolding. Nevertheless, these structures were assessed and neither was found to be very suitable for dating. The gallery half-way up the clock chamber was constructed mainly of reused timber of uncertain provenance, was lacking in sapwood, and was very fast grown. The ceiling of the clock chamber / floor to the bell chamber was also unsuitable because the timbers were boxed-heart and very fast grown.

The timbers of the support tower in the bell chamber were also assessed for dating. The posts were boxed-heart, fast-grown timber, and the rails, although halved timbers, were also predominantly fast-grown, most having between 50 and 70 rings. The braces from the bridging beams to the posts were all found to be halved timbers, each set being placed symmetrically opposite in pairs. Some were found to be slow-grown, with likely ring counts ranging from 50 to 125 years. Some retained sapwood, although in poor condition. Finally, a number of reused timbers were noted in the timber support tower. Once again, they were of marginal suitability with between 40 and 80 rings noted. The upper part of the timber support tower and the cross-beams which it supported were not accessible due to the height. Some of the highest timbers may be suitable, but they could not be assessed or sampled safely without further access scaffolding.

The spire scaffold was extensively assessed for dating, but very few of the timbers were suitable for sampling. Apart from access problems due to the height between the various stages, and lack of boarding on the scaffold frames, the vast majority of the components were from very fast-grown, boxed-hearted, small-scantling timbers averaging less than 30 rings. The cross beams which supported the spire scaffold were exceptionally fast-grown, again with less than 30 rings, whilst the main posts were unlikely to have more than 50 years growth. The best timbers for dating appeared to be the outer corner braces supporting each main post just above the floor. These seemed to have between 75 and 125 rings. Again, there were a number of reused elements in the spire scaffold frame, and like the timber support tower below, they appeared to have between 40 and 75 rings. None of the accessible timbers in the spire scaffold retained any complete sapwood, but much of the material exhibited clear heartwood/sapwood boundaries.

Sampling strategy:

The first sampling was undertaken by Robert Howard of the Nottingham University Tree-Ring dating Laboratory during 1990. The survey was somewhat limited in scope, the primary strategy being to try to date as many of the structural phases of the tower and spire as possible in order to give the RCHME chronological information which would prove useful in completing the history of the cathedral being written at the time (Cocke and Kidson 1993). Generally, only primary first-use timbers were sampled, but given this brief, both reused timbers and reset structural elements were also sampled. Access to the tower and spire was made available in conjunction with the restoration works to the spire being undertaken at the time.

The samples were numbered using the prefix ***salc*** followed by numbers ***01*** - ***08*** for the structural timbers of the clock chamber floor, ***09*** - ***16*** for the ceiling boards below the floor, ***17*** - ***27*** for the spire scaffold, and ***28*** - ***33*** for the timber support tower (Howard 1991).

The second phase of sampling was undertaken by Daniel Miles of the Oxford Dendrochronology Laboratory during 2003. Only the lowest stage of the tower was sampled adjacent to the areas where the roofs were being repaired. Given that both the clock chamber floor structure and ceiling boards had already been dated, the sampling strategy was to refine the dendrochronology. Therefore, timbers with complete sapwood were primarily targeted, and one from the 1990 sampling session (***salc01***) was re-sampled to obtain complete sapwood. The saddle brackets were also sampled to confirm that they were contemporary with the rest of the floor. Additional Baltic oak ceiling boards with heartwood/sapwood boundaries were also sampled to try to obtain a tighter felling date range. Boards on the floor beams as well as on the saddle brackets were sampled.

Ten samples were taken from the floor, and ten more samples were taken from the boards. The samples were numbered using the prefix ***sccc*** with the numbers ***1*** - ***10*** for the structural timbers and ***11*** - ***20*** for the boards. Segments of cores which had broken during drilling were labelled ***a1***, ***a2***, etc, and multiple cores were labelled ***a***, ***b***, ***c***, etc.

The final sampling took place during January 2004 by Robert Howard and Alison Arnold of Nottingham University Tree-Ring dating Laboratory. This concentrated on the timber support tower due to the results from here being somewhat inconclusive. A further twelve samples were taken with the hope that *t*-values would be sufficiently bolstered to enable some of the tentative dates to be confirmed. It was also hoped to confirm an early twelfth-century heartwood/sapwood boundary date on a reused brace (***salc33ab***) sampled in 1990. This timber was sampled again, as were other similar reused timbers, to see if they too gave similar felling date ranges. The twelve samples were labelled using the prefix ***salc*** and numbered ***43*** - ***52***, with two supplementary samples taken from timbers sampled in 1990 in order to obtain more sapwood (***salc30c*** and ***salc33c***). A complete sapwood slice (***salc31c*** was also taken by Daniel Miles from the one of the braces sampled in 1990 (***salc31ab***) and again in 2004 (***salc43***).

Section drawings of all timbers sampled are shown in Figure 25.

Methodology:

All samples were taken from what appeared to be primary first-use oak (*Quercus* spp.) timbers, or primary timbers clearly reused. The timbers chosen either had reasonably long sequences in excess of 75 rings, or some indication of sapwood. However, the timber support tower and spire scaffold, only provided short-ringed samples with less than 50 rings. The usual threshold of sample length was lowered due to the importance of the building being studied. Details of the samples taken, together with dates produced, are shown in Table 2.

Both the Oxford and Nottingham laboratories employ similar sampling and dating methods. Oxford sampled *in situ* timbers using a 16mm hollow coring bit, resulting in a 12mm core, whereas the Nottingham cores were slightly smaller at 10mm. The boards of the ceiling underneath the clock chamber floor were sampled by sawing a section from their previously cut ends.

However, the methodology for numbering samples differs slightly between the two laboratories and requires some explanation. At Oxford, samples are measured once, and the multiple suffixes ***a***, ***b***, etc. denote supplementary cores. At Nottingham, however, the primary core is measured twice, with the first reading being labelled ***a*** and the second reading being labelled ***b***. These readings are then combined at the beginning of the analysis stage to form a mean. These duplicate measurements have not been detailed in the analysis presented here (Table 2). However, supplementary cores taken during the 2004 sampling have not been measured twice but have been labelled ***c***, ie ***salc30c*** and ***salc33c***, with the original samples being labelled ***salc30ab*** and ***salc33ab***.

The labelling of one timber, the north brace to the north-west corner post of the timber support tower, is potentially confusing. This was sampled in 1990 and the core measured twice by Nottingham (***salc31ab***). It was sampled again by Nottingham in 2004, and labelled ***salc43***. A small slice retaining complete sapwood was also taken by Oxford in 2004 and was labelled ***salc31c***. All these samples have been combined to form the mean ***salc31***.

Details of the samples taken, together with dates produced, are shown in Table 2. Timbers sampled by Nottingham during 1990 were plugged and were marked by red plastic tags bearing the sample numbers.

The cores and slices taken were mounted, where necessary, and prepared by being sanded on a linisher using 60 to 1200 grit abrasive paper, and cleaned with compressed air to allow the ring boundaries to be clearly distinguished. They were then measured under a x10/x45 variable-focus microscope using a travelling stage electronically displaying displacement to a precision of 0.001mm, rounded to the nearest 0.01mm.

Two methods of analysis were used to date the samples. The initial phase of analysis was carried out at Nottingham during 1990. Various factors, including the local climate, determine the annual widths of tree rings. No two sequences of ring widths from different oaks growing in the same region are exactly alike. Indeed, there may not be a close match even when the trees are growing near to each other. Consequently, in the Nottingham Laboratory there is no attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer gives the extent of correlation between two sequences of widths or, if cross-dating, between a single sequence of widths and a master chronology, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t-value* (defined in almost any introductory book on statistics). The offset giving the maximum *t*-value of all will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out with sequences from oaks of known date suggest that a *t*-value of at least 4.5, or preferably 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984-1995).

It is standard practice in the Nottingham Laboratory to first cross-match as many as possible of the ring-width sequences and then to form a mean of the data. This is called a *site sequence* and relates to the building or phase under study. In the site sequence the width of each ring is the average of the widths in each of the sample sequences which has a ring for that particular year, all of which are stored on the computer database. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the component sample sequences individually.

The method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value method'. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the maximal *t*-value method and was successfully developed and tested in the Nottingham Laboratory (Litton and Zainodin 1991; Laxton *et al* 1988).

The samples taken during 2003 and 2004, as well as the material from 1990, were analysed at the Oxford Dendrochronology Laboratory, although the 2004 samples were prepared and measured at Notttingham. At Oxford, a slightly different method of analysis is used. After measurement, the ring-width series for each sample is plotted as a graph of width against year on log-linear graph paper. The graphs of the samples under study are then compared visually at the positions indicated by the computer and, if found satisfactory and consistent, are averaged to form a mean curve for the site or phase. The mean curve, together with the individual ring sequences, are then compared against dated master or reference chronologies to obtain absolute calendar dates for each ring.

In comparing one sequence or site sequence against another, *t*-values over 3.5 are considered significant, although in reality it is common to find *t*-values of 4 and 5 which are demonstrably spurious because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-values of 5, 6, and higher, and for these to be well replicated from different, independent chronologies and with local and regional chronologies well represented. Where two individual sequences match with a *t*-value of 10 or above, and visually exhibit exceptionally close ring patterns, they most likely came from the same parent tree. Same-tree matches can also sometimes be identified through the external characteristics of the timber itself, such as knots and shake patterns. For shorter ring sequences from the same tree, lower *t*-values are often encountered.

For this report cross-matching and dating was accomplished by using a combination of both visual matching and a process of qualified statistical comparison by computer. The ring-width series were compared on an IBM compatible 486SX computer for statistical cross-matching using a variant of the Belfast CROS program (Baillie and Pilcher 1973). A version of this and other programmes were written in BASIC by D Haddon-Reece, and latterly re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

Ascribing Felling Dates and Date Ranges

Once a tree-ring sequence has been firmly dated, a felling date, or date range, is ascribed where possible. With samples which have sapwood complete to the underside of, or including bark, this process is relatively straight forward and a *precise felling date and season* can be given. The latter depends on the completeness of the final ring, and whether it has only the spring vessels or early wood formed, or also includes the latewood or summer growth. If the sapwood is partially missing, or if only a heartwood/sapwood boundary survives, then only an *estimated felling date range* can be given for each sample. The number of sapwood rings can be estimated by using an empirically derived sapwood estimate with a given confidence limit. If no sapwood or heartwood/sapwood boundary survives, then the minimum number of sapwood rings from the appropriate regional sapwood estimate is added to the last measured ring to give a *terminus post quem* (*tpq*) or *felled after* date.

An accepted sapwood estimate for British and Irish oaks on the basis of statistics is between 10 and 55 rings with a 95% confidence range (Hillam *et al* 1987). A recent review of the geographical distribution of dated sapwood data from historic building timbers has shown that a 95% range of 9 - 41 rings is more appropriate for the southern part of England, and 11 - 41 for Wales and the Border counties (Miles 1997a). For Baltic timbers, a 95% sapwood estimate of 8 - 24 rings has been used (Tyers 1998).

Irish imports apart, documentary sources suggest that timber used in the construction of Salisbury Cathedral was imported from woodlands as far to the north-west as Trivelle and the Forest of Dean in Herefordshire, as well as from more southern counties such as Wiltshire and Hampshire (Simpson 1996; Fig 26). However, it is difficult to distinguish the Herefordshire timber from the other southern English material, as dendro-provenancing has a limited geographical application (Bridge 2000). Although the ranges are remarkably similar, this would affect the *terminus post quem* dates by two years. Despite this, the sapwood estimate of 9 - 41 years was used for all English material in this present study.

It must be emphasised that dendrochronology can only date when a tree was felled, not when the timber was used to construct the structure under study. However, it was common practice in the Middle Ages to build timber-framed structures with green or unseasoned timber and construction usually took place within twelve months of felling (Miles 1997a). Given the protracted nature of cathedral building campaigns, more caution must be shown in interpreting construction dates, especially in subsequent phases of work, as has been shown at Lincoln Cathedral (Laxton *et al* 2001). However, this can sometimes be mitigated in the light of complementary documentary evidence, as exists here at Salisbury.

Cross-matching and site chronologies:

Clock Chamber Floor at Tower Base and Miscellaneous Primary-Phase Timbers

A total of twenty samples (***salc01*** - ***salc08*** and ***sccc1*** - ***sccc10***; Table 2) were taken from seventeen timbers of the clock chamber floor (Fig 7). A further six samples were taken from five timbers which were obviously reused from what appeared to be primary-phase roof trusses (Figs 7 and 8). Three of these reused timber were from the timber support tower below the spire scaffold (***salc33***, ***salc48***, and ***salc50***), while the remaining two timbers were from the fourth stage of the spire scaffold itself (***salc25*** and ***salc26***). Only three timbers had more than 100 rings, indeed nearly half had less than 75 rings.

Three samples were taken from floor joist VI - XI, the first with a heartwood/sapwood boundary (***salc01***), and the other two with a complete sapwood complement (***sccc1a*** and ***sccc1b***). These were cross-matched together as shown in Table 3 and combined to form the same-timber mean ***sccc1***. Samples ***sccc2a*** and ***sccc2b*** taken from the same brace were similarly combined to form the same-timber mean ***sccc2*** (Table 4).

During the preliminary analysis stage, it became obvious that braces ***sccc2*** and ***sccc4*** originated from the same tree and were combined to form the same-tree mean ***sccc24*** (Table 4). Similarly, a brace (***sccc5***) and a wall post (***sccc6***) were found to originate from another tree, and were combined to form the same-tree mean ***sccc56*** (Table 4).

Following the combining of individual samples to form same-timber and same-tree means, these were cross-matched with the remaining individual samples. Thirteen sequences were found to match together with respectable *t*-values as shown in Table 5. Three other sequences (***salc03***, ***sccc8***, and ***salc33***) did not produce very high intra-site correlation with the samples, so the proposed dating positions were independently confirmed by cross-matching individually with reference chronologies (Tables 6 - 8 respectively).

All sixteen samples were then combined to form the 175-year site master ***SARUM14*** (Table 9). This was compared to over 1000 local and regional reference chronologies and was dated to the period AD

1067 - 1241 (Table 10). The matches were excellent with local regional chronologies suggesting that the timber originated from southern England or Wales.

Consideration was given as to whether the reused timbers sampled further up the tower and spire should be included in the site master. Two of these samples, ***salc25*** and ***salc48*** were found to match consistently with the other timbers from the clock chamber floor, therefore they were included. Conversely, samples ***sccc8***, ***salc03***, and ***salc33***, whilst not producing high intra-site cross-matching, did nevertheless show through their context that they originated from the same constructional phase as the others. Sample ***salc33*** dated considerably earlier than the other timbers, but still demonstrated excellent matches with the same chronologies as the site master. Even though this sample dated a century earlier, it exhibited similar jointing characteristics as adjoining timber ***salc48***. Finally, given that the timbers making up the majority of the floor framing may well have originated from different sources, there did not seem to be real advantage in segregating these into smaller site masters.

Ceiling Boarding to Clock Chamber Floor at Tower Base

Eighteen soffit boards were sampled from the former ceiling under the clock chamber floor (Fig 27: ***salc09*** - ***salc16*** and ***sccc11*** - ***sccc20***). As these boards were all riven from slow-grown oaks, they proved to be excellent material for cross-matching. Rings counts ranged from a minimum of 76 rings to 229 rings.

One sample had an area of distortion and was therefore measured in two overlapping radial sections, ***sccc14a*** and ***sccc14b***. These were cross-matched together as shown in Table 4 and combined to form the same-timber mean ***sccc14***.

During the first analysis stage, two samples, ***salc09*** and ***salc10*** were found to have originated from the same tree (Table 4). These were combined to form the same-tree mean ***salc910***.

Once the sequences had been grouped into seventeen same-tree groups, they were again cross-matched together and twelve sequences were found to match together as shown in Table 11. These were all combined to form the 238-ring site master ***SARUM15*** (Table 12). This was compared to over 1000 chronologies from the British Isles, but no outstanding matches were found. The site master was then compared with chronologies from Europe ranging from Ireland to the Baltic. The best matches were found with chronologies from eastern Europe, showing that the timber was imported from the Baltic region (Table 13). The site master matched best with the ***BALTIC1*** chronology created from the Fletcher panel paintings archive (Hillam and Tyers 1995) and ***WNCHSRT1***, a group of imported panels found at Winchester College (Lewis 1995). However, these chronologies are not closely provenanced geographically.

The remaining five sequences which did not cross-match with the other samples were compared with the site master ***SARUM15***, but no conclusive matches were found. They were then compared individually with chronologies from both the Baltic as well as the rest of Europe and Britain. Three of them were found to match: ***sccc11*** at AD 1350 (Table 14), ***salc910*** at AD 1356 (Table 15), and ***salc12*** at AD 1345 (Table 16). The Baltic chronologies with which these three individual sequences matched were generally different from those matching the site master. Best matches in two instances was with ***MAGDALN2***, composed of chests from Magdalen College, Oxford, constructed of Baltic oak (Miles and Worthington 2000). This, together with the lack of cross-matching with the other thirteen samples suggests that these boards originated from a different part of eastern Europe.

Only two samples, of 76 and 100 rings respectively, failed to date.

Spire Scaffold

Altogether a total of eleven samples were taken from the spire scaffold and its supporting cross-beams (***salc17*** - ***salc27***). Nine of these were from what appeared to be first-use timbers to the scaffold, whilst two others were reused timbers, probably from the original roofs of the cathedral (Figs 6, 28, and 29). Most of the timbers sampled were very fast grown, half of which had less than 50 rings. The two reused timbers (***salc25*** and ***salc26***) have been analysed in the section dealing with the clock chamber floor beams, and one of them (***salc25***) was dated, and included in the site master ***SARUM14***.

During the preliminary analysis stage, samples from two braces from the base of the spire scaffold, ***salc17*** and ***salc19***, were found to have originated from the same tree (Table 4). They were combined to form the same-tree mean ***salc1719***.

This sequence was found to match two other braces from the same context, ***salc18*** and ***salc20*** (Table 17). These were combined to form the site master ***SARUM16*** of 110 rings (Table 18). This site master was compared to the reference chronologies and was found to match, spanning the years AD 1229 - 1338 (Table 19).

None of the other samples matched conclusively, either with the site master or with the reference chronologies individually, primarily due to extremely low ring counts of below 50 years, combined with fast growth. The mean ring widths ranged between 2.76mm to 5.24mm.

Timber Support Tower in Bell Chamber

Twenty samples were taken from fifteen timbers of the timber support tower (Figs 7 and 30). Three of the timbers sampled were from reused primary-phase timbers which were analysed in the section dealing with the clock chamber floor beams. Two of them (***salc33*** and ***salc48***) dated, and are included in the site master ***SARUM14***.

As with the spire scaffold above, most of the timbers sampled were fast-grown, with fewer than 75 rings. Exceptions to this were some of the outer braces rising from the bridging beams to the corner posts. These were all slightly-curved and had been heart-sawn to give matching pairs. However, very little sapwood remained, and extra samples were taken from the two which retained complete sapwood to ensure a precise date should cross-matching be successful.

Initially, multiple samples from the same timber were combined to form same-timber means. Samples ***salc30ab*** and ***salc30c*** were combined to form the same-timber mean ***salc30*** (Table 4), and ***salc31ab***, ***salc31c***, and ***salc43*** were all combined to form the same-timber mean ***salc31*** (Table 20).

Next, during the preliminary analysis stage, the samples from the pairs of braces were combined at their relative offsets to give same-tree means. Same-tree matches were determined either by *t*-values over 10, or clear visual evidence on the inner face of the timbers that they originated either side of the same saw cut by the mirrored disposition of features such as shakes, knots, and angle of saw-kerfs. Thus samples ***salc28*** and ***salc31*** were combined to form the same-tree mean ***salc2831***, ***salc29*** and ***salc32*** were combined to form the same-tree mean ***salc2932***, and ***salc30*** and ***salc46*** were combined to form ***salc3046*** (Table 4).

Samples from twelve timbers making up the primary construction of the timber tower had now been reduced to nine individual sequences representing different trees. These were all cross-matched with each other, but very little intra-site correlation was found. However, two groups were found.

Sequences ***salc2831*** and ***salc2932*** were found to match together with a *t*-value of 5.17 (Table 21), and were combined to form the site master ***SARUM17*** (Table 22). This was compared to the reference chronologies and was found to span the years AD 1556-1684 (Table 23). Somewhat paradoxically, one

of the components of this, ***salc2831***, was found to have been felled during the winter of AD 1668/9, at least fifteen years earlier than the other component ***salc2932***.

The second group consisted of four samples: ***salc45***, ***salc49***, ***salc51***, and ***salc52*** (Table 24). These were combined to form the mean ***salc4552*** of 74 years, but it failed to match either the other dated samples from within the site, or with the reference chronologies.

All samples from this phase were also compared independently with the reference chronologies, but no other consistent, conclusive dating was found. The lack of good dating results for this phase can be ascribed to low ring counts, complacent growth rings, and a dearth of reference chronologies for the seventeenth century.

Interpretation and discussion:

Clock Chamber Floor at Tower Base

Of the seventeen timbers sampled, all but two dated, despite relatively low ring numbers (Fig 31). Two of these timbers retained complete sapwood. Joist VI-XI (sample ***sccc1***) was found to have been felled during the spring of AD 1242, and the north central half-joist (sample ***sccc8***) dated to the summer of AD 1242. This latter sample retained complete sapwood on the timber, which was too soft to survive coring. Therefore, a core was taken at the heartwood/sapwood transition with the last full ring boundary marked on the core end. As the rings were clearly visible running obliquely across the face of the timber, is was possible to count sixteen sapwood rings to the bark edge. It was also noted that the final ring was incomplete, which suggested summer felling. By taking the heartwood transition date of AD 1225, as marked on the core end, and adding the sixteen full sapwood rings counted on the surface, this brings the date up to AD 1241. By adding the incomplete final ring, a felling date of summer AD 1242 is determined for this timber.

The rest of the dated timbers within this floor had lost their sapwood, and therefore only felling date ranges could be given. These were generally consistent with the AD 1242 felling dates from the two joists, and showed saddle brackets were the same phase of construction as the large floors joist they supported. However, four samples had somewhat earlier felling date ranges: AD 1190 - 1222 for the north bridging beam (***salc08***) and AD 1202-34 for the south bridging beam (***sccc7***). In addition, two braces from the saddle brackets (***sccc2*** and ***sccc4***) which were found to have been from the same parent tree, were found to be felled between AD 1203-35). This suggests that these timbers had either been stock-piled, or had higher than average sapwood ring counts.

Nevertheless, the tree-ring dates give every indication that the floor is contemporary with the lantern. There is nothing to indicate that the timbers are reused or not in their original position, although the presence of the floor at this level conflicts with the original masonry detailing. Although some timbers may have been stockpiled, or have higher than average sapwood counts, other components from the saddle brackets have similar felling date ranges to the joists above, showing that the structure is all coeval. It is theoretically possible that the floor had been originally constructed at a higher level towards the top of the tower, and was lowered to its present position at the time the tower was raised and the spire constructed. It may be significant that tiebeams supported on saddle brackets are found in the roofs of early thirteenth-century French cathedrals, and these Salisbury examples may be the earliest in the British Isles, suggesting perhaps a transmission of technology from France in the early thirteenth century (Courtenay 1997).

The two recently-dated timbers felled in AD 1242 would suggest that the floor was constructed nearly ten years earlier than a preliminary assessment of the tree-ring dates indicated, although still within the

estimated 95% probability range of AD 1236-71 (Howard *et al* 1991, 41, 43). However, these precise felling dates correlate well with the royal grant of timber for the choir stalls in AD 1236 and a reasonable estimate of the date for their completion and the first use of the east arm of the cathedral (Simpson 1996, 11; Tatton-Brown *pers comm*). Unfortunately, in this instance there is no close correlation of the felling date with the provision of timber from any of the royal forests, unless they were part of a very late consignment of one hundred trees granted from the Forest of Dean in AD 1236 (Simpson 1996, 11, 18).

Ceiling boards to underside of Clock Chamber Floor at Tower Base

Sixteen out of the eighteen boards sampled from beneath the Clock Chamber floor dated (Fig 31). Tree-ring analysis has shown that the boards were imported from the south coast of the Baltic and that the trees were felled in its hinterland. Although all the samples had lost all, or most of their sapwood, ten of the dated samples retained a clear heartwood/sapwood transition. The last heartwood rings on these ten samples ranged from AD 1342 to AD 1356, giving an average heartwood/sapwood boundary date of AD 1350. By applying the 8-24 range for Baltic oak (Tyers 1998), a felling date range of AD 1358-74 is most likely. The felling date is likely to fall in the outer end of this range due to sample ***salc09*** and ***salc10*** (which are likely to be from the same tree and do not match the main group of samples) with heartwood/sapwood boundary dates of AD 1356 and 1355 respectively, and sample ***salc13*** dating to AD 1354 with no heartwood/sapwood at all. This range is significantly narrower than the range of AD 1365-92 given by the initial analysis in 1990 (Howard 1991).

Spire Scaffold

Of the eleven timbers sampled from the scaffold structure, nine were considered to be new timber at the time it was being constructed. The four outer braces rising up to the corner posts at the first stage from the supporting cross-beams were dated (Fig 31). At least two originated from the same tree (***salc17*** and ***salc19***). None retained any sapwood, but all showed clear evidence for the heartwood/sapwood transition. The dates ranged from AD 1333 to 1338, with an average heartwood/sapwood boundary date of AD 1335. By applying to this the appropriate 95% probability range of 9-41 years, a felling date range of AD 1344-76 can be given, confirming the tentative date offered by the 1990 analysis (Howard 1991).

One of two reused timbers from the fourth stage also dated. The north raking strut to the centre post (***salc25***) produced a felling date range of AD 1210-42. Its mortices and joint positions indicate that it was a reused collar from one of the original roofs, and was probably inserted following the demolition of one of the large Cathedral roofs in the seventeenth or eighteenth centuries. Gouged assembly marks recorded on three of the braces by Dr Chris Salisbury may more accurately provenance their original location in the future (Fig 32).

It is extremely significant that the dates obtained from the base of the spire scaffold show that by the time it was constructed sometime between AD 1344 and 1376, the spire must have been completed for a generation or two. Historical and architectural evidence suggests that the spire was constructed between AD 1310 and 1330, when the timbers used in the spire scaffold and those supporting it were still growing in the woods.

It is also significant that the tree-ring dates AD 1358-74 for the boarded vault or ceiling beneath the floor at the base of the lantern also fall within the AD 1344-76 period for spire scaffold, and which coincides with the first reference to storm damage to the cathedral (Table 1). Documentary sources suggest that the great storm in the middle of January AD 1362 was comparable in its intensity, and the damage inflicted, to that of late November, AD 1703 or that of recent memory in October, 1987. The

spire of Norwich Cathedral was among those brought down in AD 1362 (Wharton 1691, 415; Woodman 1996, 179). The first appeals by the bishop and chapter of Salisbury for funds to repair the damage were made to Pope Urban V in AD 1363 (Table 25). This was perhaps a natural reaction for all the deans and many of the lesser officers of the cathedral from *c* AD 1300 until the last quarter of the fourteenth century were non-resident foreigners, mostly Italian or French cardinals appointed by the Pope (Tatton-Brown 1995).

It is interesting that the appeal was made on two accounts; 'by reason of the faulty foundation.... the walls and tower are threatened with ruin' and 'there have been unwonted hurricanes..... so that the building is riven, and the bell tower for the most part fallen' (Table 25). Unfortunately, the nature of the problem(s) are not specified and one may assume that the latter plea was somewhat exaggerated to further the cause. However, there is clearly reference to both the cathedral tower and spire and to the belfry in the Close. The former complaint seems to confirm that distortion of the masonry in the crossing and adjoining bays of the choir, transepts, and nave, had already occurred as is also clear from archaeological evidence, although the blame was put on the foundations rather than the great weight of the later structures. The latter complaint suggests that the belfry was the building most seriously affected by storm damage. Unfortunately, it is not now possible to examine it for evidence. However, some or all of the papal grant which covered the years AD 1364-1369 and the supplementary funding afforded by the royal licence of AD 1366 must have been used to build the spire scaffold and the lantern ceiling (Table 25). As the latter appears never to have been coloured or decorated it may have served the purely utilitarian purpose of preventing dust and debris from the works in progress above from falling down onto the floor of the crossing.

One of the major works was probably the addition of iron reinforcement, primarily within and around the lantern but also around the exterior of the tower and associated with the scaffold in the spire (Fig 33; Reeves *et al* 1992, 387-97). The lantern's framework of iron bars was clearly designed to prevent distortion of its walls and piers by the weight of the tower and spire. The top of this extraordinary structure is directly below the stone slabs which formed the foundation of the original timber superstructure, and it supports the thickest part of the lantern walls immediately above the internal arcades (Figs 8d and 34; Morris 1996, pl xiii). The internal frame is securely linked to the external ironwork, which is covered with lead to prevent rust, by horizontal bars in square ducts cut through the walls and then filled with rammed chalk. Towards the base of the arcades individual piers are encircled with bars which are secured through the walls of the arcade passages (Reeves *et al* 1992, pl 15). The piers in the south-east corner of the lantern have an extra level of reinforcement which suggests that this part was considered to be in need of special attention.

The smiths who forged the component parts of this framework probably worked to patterns provided by a full scale wooden model. Some of them have joints which are much the same as contemporary carpenters' joints in the cathedral roofs (Reeves *et al* 1992, fig 14). One of the most characteristic, used to link together 15ft (4.58m) bars, is a joint of three 'knuckles' which are perforated and secured with a cotter (Fig 34a). These joints have usually had molten lead poured into them to ensure their fastness. Just below the parapets of the tower original structural ironwork within the masonry (Reeves *et al* 1992, fig 4) was reinforced by a bandage of iron bars linked in this way which encircled the tower.

Until 1950 there was ironwork of a similar kind which linked the top of the scaffold at Stage 9 to an iron cross at the top of the spire (Tatton-Brown 1996, pl xvii b). Unfortunately it was all taken out but a convincing reconstruction has been made from photographs and from a few pieces which have survived (Fig 6). The characteristic joints here were Y-shaped pieces the open ends of which were closed with a wedge or cotter, and eyes perforated for circular bars (Figs 6, 34b, and 34c). These joints were used at Stages 9-10 and 10-11 to link vertical bars of lengths of about 15ft (4.58m) and 10ft (3.05m) respectively to cross-pieces fixed in the masonry of the spire, and above Stage 11 through the capstone to the base of the iron cross. The cross-pieces, or something similar, were probably part of the original

structure and the vertical elements might have been added to them when the scaffold was built. However, it is perhaps more likely that all the ironwork here was contemporary and that 30ft (9.15m) or more of the spire was rebuilt after AD 1362. It is clear that the scaffold was built because of damage to, or concern about, the steeple following the storm. The present weather door and associated iron rungs up to the iron cross could not have been used without some form of access inside the spire and so presumably also date to this time.

Francis Price was the first to suggest that the scaffold was used to construct the spire and the tradition he established has persisted (Anon 1774, 16; Forsyth 1946, 86). He was quite correct to call it a scaffold, as the Oxford English Dictionary confirms, but, for many reasons, it would have been quite impractical for constructing the spire. A fifteenth-century French miniature painting shows several spires in the course of construction, all with exterior scaffolding (Fig 35). When the spire of Chichester Cathedral was rebuilt following the collapse of the central tower in AD 1861 it was from external scaffolding.

Alder poles were commonly used for temporary scaffolding or, better still, pine spars which were not only lighter than oak but straighter than alder (Salzman 1952, 248; Chapman 1907, 47, 54, 72). Clearly oak was used for the Salisbury scaffold because it was intended to be permanent. It provides structural stability by its weight suspended from the top of the spire and the struts and stays of the upper stages fitted into the angles may be effective in dampening wind pressure vibrations. The storm must have made the bishop and chapter realise that the hollow cone that was their spire had to be made accessible if it was to survive for any length of time. Lightning is unpredictable and could inflict damage not just at the top but to any part of the tower or spire, as the strikes of AD 1431, AD 1560 and AD 1741 demonstrated (Table 1). Wren, during his survey of the cathedral in AD 1668, used the scaffold for just the purpose for which it was intended when he came to the tower and spire. Commenting on the poor state of repair of the timber in the tower and spire he added '...if ye ascent to ye Spire were made easy and secure faults would sooner be spied and amended' (Wren Society 1934, 24-5).

A third phase of buttresses which might be contemporary with other work in progress following the storm is possible for there are at least five phases of medieval construction (Morris 1996, 48). However, there is sufficient documentary evidence that the bishop and chapter continued to be as much concerned with the distortion of the piers at the base of the tower as with the tower itself and the spire (Table 1; Cocke and Kidson 1993, pl 23). The strainer arches across the main transepts date *c* AD 1415-20 (Morris 1996, 48; Harvey 1987, 327) and the sawing out of the timber vault above the crossing in AD 1479-80 and the construction of the stone vault is associated with another phase of buttress construction. At the beginning of November, AD 1480 three carpenters were paid for making the cover of the central aperture in the new vault and the following month a carpenter was paid for making scaffolding for the repair of the buttress next to it on the south side. In the autumn of the following year carpenters set up scaffolding for a new buttress followed by work on its construction by the masons. The Fabric Accounts end (f.29v) in October with a purchase of lime 'for the new flying buttresses'.

The documentary record shows how from the fifteenth to the eighteenth centuries thunderstorms continued to cause damage to the tower and spire, and the scaffold must have often justified the cost of its construction by its use in the subsequent repairs (Table 1). In the middle of the eighteenth century the lightning conductor was invented by Benjamin Franklin (Dibner 1977) and was soon installed on cathedrals, thus mitigating the damage that storms could do. However, it is interesting to note that in France in the eighteenth century the clergy continued its faith in the ringing of church bells to scatter the lightning's force (Dibner 1977, 43; Ketteringham 2000, 2). This belief was probably more widespread in earlier centuries and the practice would actually have made the collapse of the belfries more likely (Heyman 1967, 248). Norwich Cathedral was one of the first cathedrals to have a conductor, 'with metallic communications to the ground', which was fitted on the recommendation of the Royal Society in AD 1770, and Salisbury acquired one early in the following century (Cocke 1996, 714; Spring 1987).

Timber Support Tower in Bell Chamber

Dendrochronology has shown this structure to be more complex than initial appearances suggest. Of the fifteen timbers sampled within the timber support tower, three clear phases of felling have been detected. The earliest are from the diagonal braces at the second stage, which are clearly reused. Two of the three sampled produced dates. The earliest is sample ***salc33*** from the north side of the tower which had a last measured ring date of AD 1131. This timber had been sampled twice, the first core (***salc33ab***) had 18 sapwood rings, and the second core (***salc33c***), taken about 8in (200mm) along the timber, had the same last measured ring date of AD 1131, but this was only the heartwood/sapwood boundary. Another brace (***salc48***) from the west side of the tower dated with a last measured ring date of AD 1222. As this included six sapwood rings, a felling date range of AD 1225-57 was produced. These two dates, varying by a century, create a major problem of interpretation. As both timbers had identical mortices from their previous uses as collars from an unidentified medieval roof, it is clear that the north brace must have dated from the same period, but has lost a century of growth rings mainly through conversion. This would suggest either that sample ***salc33*** had more than 100 sapwood rings at time of felling, or had been stockpiled for more than a century, both highly unlikely. One possible explanation is that this is an example of a sapwood *inclusion*, a phenomena rarely encountered in which an inner band of sapwood is followed by a second band of heartwood with a final sapwood band and bark edge. This has been noted in some modern living timber as well as in historic standing buildings (Miles and Worthington 1997, 168-9; Groves and Tyers *pers comm*).

The analysis has also shown a second phase of felling represented by samples ***salc28*** and ***salc31***, the south brace to the south-west corner post and the north brace to the north west corner post respectively. The latter timber produced a precise felling date of winter AD 1668/9, and as the former timber originated from the same tree, this felling date can be applied to both timbers.

The final phase of felling is represented by two further braces, the south brace to the south-east corner post, and the north brace to the north-east corner post (***salc29*** and ***salc32*** respectively). These samples were also from the same parent tree, and by taking the average heartwood/sapwood transition, a felling date range of AD 1687-1719 is given. Clearly this must indicate a late seventeenth or early eighteenth-century construction date of the timber support tower.

Apart from the second stage braces which proved to be reused thirteenth-century roof timbers, the late seventeenth century braces showed no obvious signs of reuse. Yet it is surprising that it was constructed apparently in two stages in AD 1668/9 and between AD 1687-1719. The most logical conclusion is that the AD 1668/9 timbers were either stock-piled, or were left over from some other work in the tower following the survey of Christopher Wren of AD 1668.

It perhaps is especially interesting that in December AD 1695 a thunderstorm caused 'great damage to the steeple requiring the erection of scaffolding to make repairs' (Slatter 1965, 37). Although this suggests external scaffolding, it is certainly a logical follow-on from the proposals and estimates of AD 1691 by Thomas Naish for major work in the tower, including two new floors (see Table 1). Both statements have been given a context by tree-ring dating of the timber tower. Although the latest tree-ring dates, for lack of any complete sapwood, do not give a felling year for any of the timber, taken together they suggest that the work must have begun within a few years or so of the AD 1691 proposals.

Conclusions:

The extensive use of dendrochronology, together with evidence drawn from architectural and documentary sources relating to the spire as well as associated repairs and alterations to it and to the tower, have identified four major phases of building. The earliest phase has provided two precise felling dates of spring and summer AD 1242 for the timber floor at the base of the lantern, although some timbers may possibly be slightly earlier. Whether this is *in situ*, or subsequently lowered down from a higher stage at the time the spire was constructed, it does give a date at which the central crossing area and lantern tower of the cathedral was essentially completed.

In the top storey of the tower, the timber support tower underpinning the spire scaffold was found to have been inserted between AD 1687-1719, and most likely shortly after the damage suffered in AD 1695. This structure was constructed reusing some timber from the thirteenth-century cathedral roofs, stock-piled material from the time of Christopher Wren's survey of AD 1668, as well as newly felled timbers.

Whilst there were no timber elements to date the spire itself, stylistic parallels and documentary references suggest that it was constructed between AD 1310 and AD 1330. However, the internal spire scaffold, long thought to be contemporary, has now been shown to date from a generation or two later, between AD 1344 and 1376. This also coincides with the insertion of a ceiling of imported Baltic oak at the base of the tower, dendrochronologically-dated to between AD 1358-74, suggesting that the two operations could be related. Further documentary references suggest that this work might have been required to repair damage to the spire following an exceptionally severe storm during January AD 1362. This would have necessitated access to be provided to the inside of the spire, and would give an excellent *raison d'ètre* for the insertion of the internal scaffold frame.

The sampling has shown that much of the timber used in the spire scaffold were of small, boxed-heart timbers, as was some of the timbers used in the timber support tower below and the floor to the clock chamber. Here too a number of timbers which had been halved, or quartered, converted from larger trees. The Baltic oak boarding applied to the underside of the Clock Chamber ceiling was found to have originated from large, very slow-grown trees which had been converted radially.

This research, carried out over the past fifteen years, has gone some way towards finally resolving one of the major question marks in the building of the spire and tower at Salisbury, identifying a hitherto unknown phase of construction in the third quarter of the fourteenth century.

Further recommendations:

Should access be available in the future to the upper reaches of the timber support tower in the bell chamber, then the opportunity should be taken to properly assess these timbers to see if they might help clarify the phasing of this structure. Similarly, should scaffolding ever be required within the lower stage of the tower to gain access to the underside of the gallery and the bell chamber floor above, then these elements should also be assessed for dendrochronological potential. A careful study of the masonry at these points might also assist in the further understanding for the medieval and post-medieval phasing of the tower.

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Table 1: Chronicle of damage and repairs to the spire and tower of Salisbury Cathedral

DATE	EVENT	DAMAGE/REPAIR	REFERENCE
January, 1362	hurricanes	`the building is riven, the bell tower mostly fallen'	Cal. Papal Registers: Petitions I [1342-1419], 462
October, 1363	faulty foundations	`the walls and tower are threatened with ruin'	Papal Letters IV [1362-1404], 89
July, 1387	repair of the steeple discussed in Chapter	steeple `threatened ruin'	Pugh and Crittall 1956, 176
1423	documentary record (patent)	`the stone tower in the middle of Salisbury Cathedral is ruinous and the dean and chapter are empowered to appropriate £50 annually for its repair'	Pugh and Crittall 1956, 178
1429	documentary record (licence)	certain tithes appropriated `to maintain the tall spire steeple of that fabric in repair'	Cocke and Kidson 1993, 11
1431	lightning	spire set on fire	Wheeler 1889, 9
1479-81	construction work	stone vault and new flying buttresses built at base of tower	Fabric Accounts, Salisbury
May, 1560	lightning	'a continued fissure was made from the top for sixty feet downwards'	Ayre 1850, 1234
1641	lightning	spire set on fire	Wheeler 1889, 9
Summer, 1668	survey of the cathedral by Sir Christopher Wren	damage due to lightning identified at the base of the sire and higher up. A series of `bandages' later put around the spire	Wren Society Publications, 1934, 21-26
December, 1695	thunderstorm	great damage to the steeple requiring the erection of scaffolding to make repairs	Slatter 1965, 37
June, 1741	lightning strike through window of upper floor of tower	fire started and spread to lower floor of tower and also to the base of the spire	Price 1753, 60
1762	minute of Chapter meeting, 8th October, 1762	a new weather vane atop the spire, four small oval windows made in the spire, the floor and windows in the tower to be repaired	Tatton-Brown 1996, 66, n13
Early 19th century	first lightning conductor fitted to the spire		Spring 1987, 56

Table 2: Summary of tree-ring dating

SALISBURY CATHEDRAL - Tower and Spire

Sample number & type		Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges (AD)
Clock Chamber floor at tower base										
salc01	*c*	*Joist VI - XI*	*1165-1227*	*1226*	*1*	*63*	*3.11*	*1.12*	*0.254*	*1235-67*
sccc1a	*c*	*ditto*	*1176-1241*	*1228*	*13¼C*	*66*	*2.73*	*0.78*	*0.197*	
sccc1b	*c*	*ditto*	*1210-1241*	*1227*	*14¼C*	*32*	*2.41*	*0.75*	*0.226*	
* *sccc1*		Mean of ***salc01*** + ***sccc1a*** + ***sccc1b***	1165-1241	1227	14¼C	77	2.97	1.07	0.205	Spring 1242
* *salc02*	c	Joist V - XII	1155-1221	1221	H/S	67	3.35	0.95	0.184	1230-62
* *salc03*	c	South central half-joist	1136-1205	1204	1	70	1.78	0.69	0.187	1213-45
* *salc04*	c	Joist IIII - XIII	1162-1217	1217	H/S	56	4.45	1.10	0.186	1226-58
* *salc05*	c	Joist III - XIIII	1167-1211	1211	H/S	45	4.08	1.15	0.243	1220-52
* *salc06*	c	Joist II - XV	1178-1228	1228	H/S	51	3.68	0.84	0.196	1237-69
* *salc07*	c	Joist I - XVI	1164-1218	1218	H/S	55	3.65	1.12	0.194	1227-59
* *salc08*	c	North beam	1100-1181	1181	H/S	82	1.51	0.41	0.219	1190-1222
sccc2a	*c*	*North brace XI*	*1086-1163*			*78*	*1.77*	*0.42*	*0.215*	
sccc2b	*c*	*ditto*	*1154-1192*	*1192*	*H/S*	*39*	*1.47*	*0.34*	*0.266*	
sccc2		*Mean of* ***sccc2a*** + ***sccc2b***	*1086-1192*	*1192*	*H/S*	*107*	*1.68*	*0.43*	*0.234*	*(1203-35)*
* *sccc3*	c	North brace X	1175-1213	1213	H/S	39	3.06	1.11	0.172	1222-54
sccc4	*c*	*North brace VIIII*	*1067-1195*	*1195*	*H/S*	*129*	*1.55*	*0.40*	*0.230*	*(1203-35)*
* *sccc24*		Mean of ***sccc2*** + ***sccc4***	1067-1195	1194	1	129	1.64	0.39	0.228	(1203-35)
sccc5	*c*	*East brace to north bridging beam*	*1146-1217*	*1217*	*H/S*	*72*	*1.31*	*0.41*	*0.228*	*1226-58*
sccc6	*c*	*North-east wall-post to north bridging beam*	*1126-1216*	*1216*	*H/S*	*91*	*1.51*	*0.77*	*0.220*	*(1225-58)*
* *sccc56*		Mean of ***sccc5*** + ***sccc6***	1126-1217	1217	H/S	92	1.52	0.67	0.217	1226-58
* *sccc7*	c	South bridging beam	1083-1193	1193	H/S	111	1.62	0.54	0.186	1202-34
* *sccc8*	c	North central half-joist	1141-1225	1225	H/S+16½C NM85		1.64	1.47	0.241	Summer 1242
sccc9	c	West horizontal strut to north bridging beam brace	-		H/S	40	2.32	1.03	0.233	
sccc10	c	North brace XVI	-			81	2.24	1.15	0.349	
* = ***SARUM14*** **Site Master**			**1067-1241**			**175**	**2.20**	**0.55**	**0.164**	

Table 2 (continued): Summary of tree-ring dating

Sample number & type		Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges (AD)
Boards - Underside of tower base floor (Baltic imports)										
salc09	*s*	*Board on side of west spur to N beam brace*	*1239-1356*	*1356*	*H/S*	*118*	*1.20*	*0.33*	*0.205*	*(1364-80)*
salc10	*s*	*Board on west brace to north beam*	*1233-1355*	*1355*	*H/S*	*123*	*1.17*	*0.34*	*0.216*	*(1364-80)*
salc910		Mean of ***salc09*** + ***salc10***	1233-1356	1356	H/S	124	1.18	0.32	0.209	1364-80
salc11	s	Board on west saddle to north bridging beam	-		1	100	1.67	0.31	0.150	
salc12	s	Board on west saddle to south bridging beam	1219-1345	1344	1	127	1.33	0.25	0.166	1353-69
† ***salc13***	s	Board on south central half-joist	1178-1354			177	0.94	0.20	0.173	After 1362
salc14	s	Board on south central half-joist	-			76	1.41	0.30	0.201	
† ***salc15***	s	Board on E horizontal strut to S beam brace	1235-1349			115	1.15	0.43	0.207	After 1357
† ***salc16***	s	Board on E horizontal strut to N beam brace	1198-1330			133	0.96	0.22	0.211	After 1338
sccc11	s	Board on east saddle to north bridging beam	1261-1350	1350	H/S	90	1.77	0.56	0.210	1358-74
† ***sccc12***	s	Board on east brace to north bridging beam	1183-1347	1342	5	165	0.91	0.47	0.198	1350-64
† ***sccc13***	s	Board on north brace X	1199-1352	1349	3	154	1.04	0.20	0.150	1349-63
sccc14a	*s*	*Board on joist VII - X (north)*	*1159-1288*			*130*	*0.91*	*0.20*	*0.200*	
sccc14b	*s*	*ditto*	*1249-1352*	*1350*	*2*	*104*	*0.68*	*0.17*	*0.155*	
† ***sccc14***		Mean of ***sccc14a*** + ***sccc14b***	1159-1352	1350	2	194	0.81	0.24	0.180	1358-74
† ***sccc15***	s	Board on joist VII - X (middle)	1259-1351	1350	1	93	1.74	0.46	0.166	1358-74
† ***sccc16***	s	Board on joist VII - X (south)	1248-1350	1350	1	103	1.21	0.28	0.165	1358-74
† ***sccc17***	s	Board on soffit of W horiz strut to N brace	1117-1345			229	0.72	0.23	0.192	After 1353
† ***sccc18***	s	Board on joist II - XV (north)	1205-1346			142	1.12	0.33	0.178	After 1354
† ***sccc19***	s	Board on joist II - XV (south)	1182-1348			167	0.95	0.33	0.217	After 1356
† ***sccc20***	s	Board on joist IIII - XIII	1205-1352	1351	1	148	0.99	0.26	0.232	1359-75
† = ***SARUM15***		**Site Master**	**1117-1354**	**1350**		**238**	**0.98**	**0.23**	**0.159**	**1358-74**

Table 2 (continued): Summary of tree-ring dating

Sample number & type		Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges (AD)
Bell Chamber - Timber Support Tower										
First-use timbers										
salc30ab	*c*	W brace to SW corner post	-		*13*	*72*	*2.44*	*0.63*	*0.187*	
salc30c	*c*	*ditto*	-		*15C*	*71*	*2.52*	*0.64*	*0.196*	
salc30		*Mean of* ***salc30ab*** + ***salc30c***	-		*15C*	*74*	*2.48*	*0.63*	*0.186*	
salc46	*c*	E brace to SE corner post	-		*12*	*75*	*2.30*	*0.89*	*0.147*	
salc3046		Same-tree mean of ***salc30*** + ***salc46***	-		15C	79	2.39	0.66	0.150	
salc29	*c*	S brace to SE corner post	*1569-1684*	*1679*	*5*	*116*	*1.28*	*0.46*	*0.193*	*(1687-1719)*
salc32	*c*	N brace to NE corner post	*1580-1678*	*1677*	*1*	*99*	*1.78*	*0.42*	*0.171*	*(1687-1719)*
‡ *salc2932*		Same-tree mean of ***salc29*** + ***salc32***	1569-1684	1678	6	116	1.51	0.44	0.179	1687-1719
salc44	c	W brace NW corner post	-		H/S	43	2.02	0.54	0.150	
salc45	c	E brace NE corner post	23-67	67	H/S	45	2.36	0.61	0.176	
salc47	c	NW corner post	-		1	56	2.93	1.38	0.196	
salc49	c	N lower rail	2-70	70	H/S	69	2.43	0.59	0.173	
salc51	c	W lower rail	1-62	62	H/S	62	2.18	0.72	0.202	
salc52	c	E lower rail	9-74	65	9	66	2.03	0.71	0.218	
salc4552		Mean of ***salc45*** + ***salc49*** + ***salc51*** + ***salc52***	1-74			74	2.18	0.53	0.166	
Reused or stockpiled timbers from 1669 repairs by Sir Christopher Wren										
salc28	*c*	S brace to SW corner post	*1556-1648*	*1648*	*H/S*	*93*	*2.01*	*0.80*	*0.184*	*(Winter 1668/9)*
salc31ab	*c*	N brace to NW corner post	*1567-1648*	*1648*	*H/S*	*82*	*1.87*	*0.89*	*0.199*	*1657-89*
salc43	*c*	*ditto*	*1571-1662*	*1649*	*13*	*92*	*1.69*	*0.51*	*0.201*	
salc31c	*s*	*ditto*	*1630-1668*	*1648*	*20C*	*39*	*1.42*	*0.32*	*0.263*	
salc31		*Mean of* ***salc31ab*** + ***salc43*** + ***salc31c***	*1567-1668*	*1648*	*20C*	*102*	*1.76*	*0.74*	*0.205*	*Winter 1668/9*
‡ *salc2831*		Same-tree mean of ***salc28*** + ***salc31***	1556-1668	1648	20C	113	1.91	0.81	0.200	
‡ = *SARUM17*		**Site Master**	**1556-1684**			**129**	**1.76**	**0.74**	**0.170**	
Reused timbers from primary phase roofs										
salc33ab	*c*	N diagonal brace 2nd stage (reused timber)	*1056-1131*	*1113*	*18*	*76*	*2.90*	*1.27*	*0.255*	
salc33c	*c*	*ditto*	*1053-1131*	*1131*	*H/S*	*79*	*2.71*	*1.14*	*0.244*	
* *salc33*		Mean of ***salc33ab*** + ***salc33c***	1053-1131			79	2.82	1.20	0.240	[1] After 1140
* *salc48*	c	W diagonal brace 2nd stage (reused timber)	1148-1222	1216	6	75	2.99	1.06	0.216	1225-57
salc50	c	S diagonal brace 2nd stage (reused timber)	-			37	2.36	0.55	0.190	

[1]This is probably a sapwood inclusion, therefore only a *ternminus post quem* date has been quoted

Table 2 (continued): Summary of tree-ring dating

Sample number & type		Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width mm	Std devn mm	Mean sens mm	Felling seasons and dates/date ranges (AD)
Spire - Scaffold frame										
First-use timbers										
salc17	*c*	E brace at base of E corner	*1253-1338*	*1338*	*H/S*	*86*	*2.28*	*1.30*	*0.253*	*1347-79*
§ ***salc18***	c	N brace at base of N corner	1253-1333	1333	H/S	81	2.89	1.81	0.141	1342-74
salc19	*c*	W brace at base of W corner	*1229-1337*	*1337*	*H/S*	*109*	*2.38*	*1.15*	*0.213*	*(1347-79)*
§ ***salc20***	c	S brace at base of S corner	1251-1333	1333	H/S	83	1.83	1.32	0.190	1342-74
§ ***salc1719***		Same-tree mean of ***salc17*** + ***salc19***	1229-1338	1338	H/S	110	2.46	1.24	0.220	1347-79
salc21	c	North - south supporting cross-beam	-		H/S	27	5.34	1.47	0.145	
salc22	c	South corner post	-		H/S	47	3.39	1.44	0.189	
salc23	c	Central post first stage	-		H/S	47	4.33	0.90	0.137	
salc24	c	Central post second stage	-		H/S	46	3.44	0.92	0.236	
salc27	c	East corner post first stage	-		H/S	44	2.76	1.28	0.178	
§ = *SARUM16* Site Master			**1229-1338**	**1335**		**110**	**2.50**	**1.39**	**0.160**	**1344-76**
Reused timbers from primary phase roofs										
* ***salc25***	c	N raking strut to centre post 4th stage (reused)	1123-1201		H/S	79	2.87	0.59	0.143	1210-42
salc26	c	E raking strut to centre post 4th stage (reused)	-			76	2.81	0.96	0.232	

Key: *, †, §, ‡ = sample included in site-masters; c = core; s = section; ¼C,½C,C = bark edge present, partial or complete ring: ¼C = spring (ring not measured), ½C = summer/autumn, or C = winter felling (ring measured); H/S bdry = heartwood/sapwood boundary - last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity. Sapwood estimate (95% confidence) of 9 - 41 used for English timbers (Miles 1997a), 8 - 24 for Baltic oak boards (Tyers 1998)

Table 3: Matrix of *t* -values and overlaps for components of *sccc1*

Sample:	***sccc1a***	***sccc1b***
Last ring date AD:	1241	1241
salc01	6.69 / 52	6.88 / 18
	sccc1a	11.20 / 32

Table 4: Combining of individual samples to form same-tree means

Samples:	*t - value:*	*overlap:*	*combined mean:*
sccc2a + sccc2b	2.40	10	***sccc2***
sccc2 + sccc4	14.20	107	***sccc24***
sccc5 + sccc6	13.71	71	***sccc56***
salc09 + salc10	18.29	117	***salc910***
sccc14a + sccc14b	15.04	40	***sccc14***
salc17 + salc19	13.85	85	***salc1719***
salc30ab + salc30c	16.32	69	***salc30***
salc30 + salc46	5.98	70	***salc3046***
salc29 + salc32	11.56	99	***salc2932***
salc28 + salc31	8.20	82	***salc2831***
salc33ab + salc33c	22.40	76	***salc33***

Table 5: Matrix of t -values and overlaps for components of ***SARUM14***

Sample:	***salc03***	***salc04***	***salc05***	***salc06***	***salc07***	***salc08***	***sccc1***	***sccc24***	***sccc3***	***sccc56***	***sccc7***	***sccc8***	***salc25***	***salc33***	***salc48***
Last ring date AD:	1205	1217	1211	1228	1218	1181	1241	1195	1213	1217	1193	1225	1201	1131	1222
salc02	2.44 51	5.83 56	6.98 45	5.28 44	5.81 55	1.37 27	4.68 57	7.57 41	3.68 39	4.31 63	3.96 39	2.40 67	4.47 47	0.00 0	2.80 67
	salc03	2.60 44	3.86 39	1.35 28	4.16 42	2.29 46	3.04 41	3.76 60	2.10 31	1.62 70	1.78 58	1.01 65	2.96 66	0.00 0	3.79 58
		salc04	3.58 45	3.71 40	7.73 54	0.00 20	5.27 53	5.33 34	5.09 39	2.78 56	3.31 32	3.12 56	5.70 40	0.00 0	3.76 56
			salc05	2.12 34	3.65 45	1.49 15	2.08 45	5.39 29	2.92 37	2.56 45	3.44 27	0.59 45	2.60 35	0.00 0	2.24 45
				salc06	5.04 41	0.00 0	6.67 51	3.96 18	4.30 36	3.07 40	2.31 16	3.29 48	6.74 24	0.00 0	3.42 45
					salc07	0.00 18	4.89 54	5.85 32	6.34 39	2.79 54	2.06 30	3.61 55	5.20 38	0.00 0	4.54 55
						salc08	0.00 17	2.71 82	0.75 7	6.21 56	7.64 82	0.85 41	3.30 59	0.88 32	1.74 34
							sccc1	5.11 31	3.03 39	2.81 53	1.88 29	5.12 61	4.99 37	0.00 0	5.04 58
								sccc24	3.11 21	4.61 70	4.06 111	2.34 55	6.00 73	4.30 65	5.58 48
									sccc3	3.41 39	2.47 19	1.78 39	2.40 27	0.00 0	3.27 39
										sccc56	4.59 68	1.98 77	2.88 76	0.00 6	2.88 70
											sccc7	2.09 53	5.45 71	1.22 49	3.85 46
												sccc8	3.54 61	0.00 0	2.39 75
													salc25	0.51 9	5.64 54

Table 6: Dating of ***salc03*** (AD 1136-1205) against reference chronologies at AD 1205

Reference chronology	Spanning	Overlap	t-value
GLOUCBLF *(Hillam and Groves 1993)*	1076-1219	70	3.70
BRISTOL *(Hillam 1994)*	770-1320	70	3.73
SWANMED *(Groves and Hillam 1981)*	938-1192	57	3.84
LONDON *(Tyers pers com)*	413-1728	70	3.80
LGHTSHW1 *(Groves 1998)*	1106-1270	70	4.00
BAGULEY2 *(Leggett 1980)*	1037-1290	70	4.18
WINCATH2 *(Miles and Worthington 1998)*	1098-1317	70	4.10
COXWELL *(Siebenlist-Kerner et al 1978)*	1043-1267	70	4.15
PETERC *(Tyers 1999a)*	887-1225	70	4.42
LUDLOW2 *(Miles and Haddon-Reece 1993)*	1139-1274	67	4.68

Table 7: Dating of ***sccc8*** (AD 1141-1225) against reference chronologies at AD 1225

	Reference chronology	Spanning	Overlap	t-value
	THEBOLD1 *(Miles and Haddon-Reece 1995)*	1113-1315	85	4.06
	PLOWDEN1 *(Miles and Haddon-Reece 1993)*	977-1301	85	4.13
‡	ROCKBORN *(Miles and Haddon-Reece 1995)*	1094-1263	85	4.26
	DOULTING *(Miles and Worthington 2000)*	1154-1287	72	4.30
	READING *(Groves et al 1999)*	1160-1407	66	4.37
	CRAWLEYC *(Tyers and Barefoot unpubl)*	1170-1338	56	4.66
	HANTS02 *(Miles 2003)*	443-1972	85	5.01
	SOUTH *(Hillam and Groves 1994)*	406-1594	85	5.39
	MEARE *(Bridge 2002)*	1156-1314	70	5.67
	SARUM3X *(Miles 2002a)*	1035-1254	85	5.72

‡ Component of HANTS02

Table 8: Dating of ***salc33*** (AD 1053-1131) against reference chronologies at AD 1131

	Reference chronology	Spanning	Overlap	t-value
	MASTERAL *(Haddon-Reece and Miles 1993)*	404-1987	79	4.18
	WHTOWER1 *(Miles and Worthington 1997)*	907-1092	40	4.56
	SARUM9 *(Miles in prep)*	1057-1250	75	4.87
	DORE1 *(Tyers and Boswijk 1998)*	1073-1195	59	4.97
	RIVRSDWN *(Miles and Worthington 2001)*	1074-1326	58	5.17
*	GLAST *(Bridge 1983)*	1095-1334	37	5.43
	ENGLAND *(Baillie and Pilcher 1982)*	404-1981	79	5.46
	LONDON *(Tyers pers comm)*	413-1728	79	5.53
	SARUM3X *(Miles 2002a)*	1035-1254	79	6.64
	SWANMED *(Groves and Hillam 1981)*	938-1192	79	6.82
	SENG98 *(Bridge 1998a)*	944-1790	79	6.98

* Component of MASTERAL

Table 9: Ring-width data for site master curve

SARUM14 AD 1053-1241 Salisbury Cathedral Tower - Thirteenth-century English material 18-timber / 16 tree mean

189 rings, starting date AD 1053

ring widths (0.01mm)										number of samples in master									
333	339	484	504	489	576	498	509	417	402	1	1	1	1	1	1	1	1	1	1
534	549	304	396	348	323	288	274	229	237	1	1	1	1	2	2	2	2	2	2
323	243	234	317	285	207	260	246	159	203	2	2	2	2	2	2	2	2	2	2
246	241	312	229	195	184	238	152	149	208	3	3	3	3	3	3	3	3	3	3
273	215	198	185	257	300	234	265	212	219	3	3	3	3	3	3	3	4	4	4
236	179	219	205	190	201	168	135	129	156	4	4	4	4	4	4	4	4	4	4
159	178	218	160	157	193	161	167	151	186	4	4	4	4	4	4	4	4	4	4
256	222	212	187	199	206	147	149	188	198	5	5	5	6	6	6	6	6	6	5
197	211	221	245	198	222	188	282	294	301	5	5	5	6	6	6	6	6	7	7
259	255	284	232	223	282	264	236	260	247	7	7	7	7	7	8	8	8	8	8
246	210	196	218	246	212	227	214	174	221	8	8	9	9	9	9	9	9	9	10
211	280	313	267	286	336	342	278	286	259	10	11	12	12	13	13	13	13	13	13
263	284	269	319	215	302	275	201	210	288	13	13	14	14	14	15	15	15	15	14
253	213	282	301	317	214	316	331	260	275	14	14	14	14	14	14	14	14	14	14
350	293	310	285	258	200	233	249	272	254	14	13	13	12	12	12	12	12	12	11
253	209	252	241	209	288	252	294	292	203	11	11	11	10	10	10	10	10	10	9
221	256	265	253	233	166	220	270	268	264	9	8	8	8	8	6	5	5	5	4
218	209	260	339	284	276	391	202	143	171	3	3	3	2	2	2	1	1	1	1
131	177	171	164	217	194	181	119	165		1	1	1	1	1	1	1	1	1	

Table 10: Matrix of *t* -values and overlaps for components of ***SARUM15*** + ***sccc11***, ***salc910***, and ***salc12***

Sample:	***salc15***	***salc16***	***sccc12***	***sccc13***	***sccc14***	***sccc15***	***sccc16***	***sccc17***	***sccc18***	***sccc19***	***sccc20***	***sccc11***	***salc910***	***salc12***
Last ring date AD:	1349	1330	1347	1352	1352	1351	1350	1345	1346	1348	1352	1350	1356	1345
salc13	10.30	8.12	4.37	5.89	4.62	4.50	4.98	7.33	9.06	6.29	7.74	0.08	3.39	3.36
	115	133	165	154	175	93	103	168	142	167	148	90	122	127
	salc15	5.54	2.33	3.40	3.54	5.64	4.42	7.88	8.70	8.66	5.43	2.79	2.06	2.90
		96	113	115	115	91	102	111	112	114	115	89	115	111
		salc16	8.68	4.21	6.09	4.39	3.43	9.81	6.46	7.22	5.42	2.80	3.47	3.84
			133	132	133	72	83	133	126	133	126	70	98	112
			sccc12	3.67	4.53	2.61	3.23	5.45	6.04	4.50	3.97	0.00	1.85	0.91
				149	165	89	100	163	142	165	143	87	115	127
				sccc13	1.75	3.55	0.96	5.26	3.76	4.70	3.93	0.00	4.22	1.75
					154	93	103	147	142	150	148	90	120	127
					sccc14	3.69	3.04	3.93	4.77	2.86	5.97	0.82	0.35	0.60
						93	103	187	142	167	148	90	120	127
						sccc15	5.65	5.13	6.20	6.14	5.00	1.69	1.00	1.84
							92	87	88	90	93	90	93	87
							sccc16	4.32	9.54	3.20	7.10	0.56	1.64	1.45
								98	99	101	103	90	103	98
								sccc17	6.04	7.68	5.65	1.64	2.44	3.16
									141	164	141	85	113	127
									sccc18	8.05	8.11	1.21	1.93	2.52
										142	142	86	114	127
										sccc19	6.61	0.89	1.62	1.78
											144	88	116	127
											sccc20	0.38	3.18	2.47
												90	120	127
												sccc11	1.77	4.27
													90	85
													salc910	3.96
														113

Table 11: Dating of ***SARUM14*** (AD 1067-1241) against reference chronologies at AD 1241

	Reference chronology	Spanning	Overlap	t-value
	SARUM2 *(Miles 2002a)*	1106-1213	108	7.84
	WALES97 *(Miles 1997b)*	404-1981	189	10.71
	GLOUCBLF *(Hillam and Groves 1993)*	1076-1219	144	10.71
*	REF75 *(Fletcher 1977)*	845-1298	189	10.95
	LONDON *(Tyers pers comm)*	413-1728	189	11.01
	MASTERAL *(Haddon-Reece and Miles 1993)*	404-1987	189	12.19
	SENG98 *(Bridge 1998a)*	944-1790	189	12.25
	HANTS02 *(Miles 2003)*	443-1972	189	12.28
	SOUTH *(Hillam and Groves 1994)*	406-1594	189	13.29
	SARUM3X *(Miles 2002a)*	1035-1254	189	13.40

* Component of MASTERAL

Table 12: Ring-width data for site master curve

SARUM15 AD 1117-1354 Salisbury Cathedral - ceiling at bottom of Tower - Baltic imported material 12-timber mean

238 rings, starting date AD 1117

ring widths (0.01mm)										number of samples in master									
101	72	93	117	86	141	185	214	149	114	1	1	1	1	1	1	1	1	1	1
87	50	50	59	42	83	100	96	86	135	1	1	1	1	1	1	1	1	1	1
115	102	83	90	113	79	82	93	81	91	1	1	1	1	1	1	1	1	1	1
116	115	113	139	104	47	97	75	83	85	1	1	1	1	1	1	1	1	1	1
66	111	89	115	66	56	64	67	60	76	1	1	2	2	2	2	2	2	2	2
87	109	81	83	102	98	78	86	83	74	2	2	2	2	2	2	2	2	2	2
84	61	65	56	70	75	147	150	137	134	2	3	3	3	3	4	5	5	5	5
122	107	98	122	115	96	106	112	151	108	5	5	5	5	5	5	5	5	5	5
107	128	120	149	150	105	121	121	103	87	5	6	7	7	7	7	7	7	9	9
94	108	88	102	107	108	74	81	89	79	9	9	9	9	9	9	9	9	9	9
73	63	108	71	78	91	81	67	98	75	9	9	9	9	9	9	9	9	9	9
90	106	131	125	95	102	88	103	100	90	9	9	9	9	9	9	9	9	10	10
95	73	106	92	91	118	125	105	124	112	10	10	10	10	10	10	10	10	10	10
120	121	121	142	144	134	127	113	120	94	10	11	11	11	11	11	11	11	11	11
92	80	139	108	94	128	104	131	91	116	11	11	12	12	12	12	12	12	12	12
89	100	96	102	126	105	115	137	132	121	12	12	12	12	12	12	12	12	12	12
84	87	109	114	112	90	103	104	104	113	12	12	12	12	12	12	12	12	12	12
96	123	117	100	103	85	83	96	109	117	12	12	12	12	12	12	12	12	12	12
103	106	105	98	96	123	105	89	89	96	12	12	12	12	12	12	12	12	12	12
87	92	94	83	96	101	97	93	87	114	12	12	12	12	12	12	12	12	12	12
96	98	87	88	87	77	80	68	93	84	12	12	12	12	12	12	12	12	12	12
92	86	80	66	84	85	73	75	74	90	12	12	12	12	11	11	11	11	11	11
77	73	102	78	81	80	74	81	86	91	11	11	11	11	11	11	11	11	11	10
93	78	104	114	95	94	107	83			9	8	7	6	5	4	1	1		

Table 13: Dating of ***SARUM15*** (AD 1117-1354) against reference chronologies at AD 1354

Reference chronology	Spanning	Overlap	t-value
SARUMBP3 *(Miles and Worthington 2000)*	1088-1400	238	4.35
MAGDALN3 *(Miles and Worthington 2000)*	1222-1494	133	4.78
GRIMSBY1 *(Groves 1992)*	1100-1405	238	4.84
SYM-T9 *(Tyers pers comm)*	1133-1333	201	5.34
REF2 *(Fletcher 1977)*	1244-1611	111	5.47
HULLBLDS *(Hillam 1991)*	1148-1464	207	6.32
GDANSK *(Eckstein pers comm)*	996-1985	238	6.81
REF4 *(Fletcher 1977)*	1124-1403	231	7.16
WNCHSTR1 *(Lewis 1995)*	1207-1495	148	8.24
BALTIC1 *(Hillam and Tyers 1995)*	1156-1597	199	10.99

Table 14: Dating of ***sccc11*** (AD 1261-1350) against reference chronologies at AD 1350

Reference chronology	Spanning	Overlap	t-value
GDANSK *(Eckstein pers comm)*	996-1985	90	3.61
SYM-T9 *(Tyers pers comm)*	1133-1333	73	3.78
BALTIC2 *(Hillam and Tyers 1995)*	1257-1615	90	4.07
GRIMSBY1 *(Groves 1992)*	1100-1405	90	4.21
MAGDALN2 *(Miles and Worthington 2000)*	1080-1416	90	6.39

Table 15: Dating of ***salc910*** (AD 1233-1356) against reference chronologies at AD 1356

Reference chronology	Spanning	Overlap	t-value
STHELEN3 *(Miles and Haddon-Reece 1995)*	1188-1397	124	3.53
BALTIC2 *(Hillam and Tyers 1995)*	1257-1615	100	3.91
GDANSK *(Eckstein pers comm)*	996-1985	124	3.99
GRIMSBY1 *(Groves 1992)*	1100-1405	124	4.40
WHTOWER2 *(Miles and Worthington 1997)*	1109-1337	105	5.10
REF4 *(Fletcher 1977)*	1124-1403	124	5.36
NWCOLLG2 (*Worthington and Miles in prep*)	1086-1357	124	5.43

Table 16: Dating of ***salc12*** (AD 1219-1345) against reference chronologies at AD 1345

Reference chronology	Spanning	Overlap	t-value
STHELEN2 *(Miles and Haddon-Reece 1995)*	1216-1416	127	3.58
GDANSK *(Eckstein pers comm)*	996-1985	127	3.97
GRIMSBY1 *(Groves 1992)*	1100-1405	127	4.11
SYM-T9 *(Tyers pers comm)*	1133-1333	115	4.28
REF2 *(Fletcher 1977)*	1244-1611	102	4.78
NWCOLLG2 (*Worthington and Miles in prep*)	1086-1357	127	4.83
BALTIC2 *(Hillam and Tyers 1995)*	1257-1615	89	5.15
MAGDALN2 *(Miles and Worthington 2000)*	1080-1416	127	6.46

Table 17: Matrix of *t* -values and overlaps for components of ***SARUM16***

Sample:	***salc1719***	***salc20***
Last ring date AD:	1338	1333
salc18	4.52	4.65
	81	81
	salc1719	6.59
		83

Table 18: Ring-width data for site master curve

SARUM16 AD 1229-1338 Salisbury Cathedral - spire scaffold - English material 4-timber / 3-tree mean

110 rings, starting date AD 1229

ring widths (0.01mm)										number of samples in master									
111	134	115	143	265	246	262	209	341	269	1	1	1	1	1	1	1	1	1	1
361	331	236	340	440	416	444	470	462	466	1	1	1	1	1	1	1	1	1	1
523	447	524	454	582	594	577	556	597	600	1	1	2	2	3	3	3	3	3	3
565	482	443	423	325	327	286	315	321	367	3	3	3	3	3	3	3	3	3	3
315	218	258	238	318	235	166	146	224	230	3	3	3	3	3	3	3	3	3	3
234	259	207	211	151	131	162	215	182	141	3	3	3	3	3	3	3	3	3	3
159	184	177	221	207	200	138	133	122	140	3	3	3	3	3	3	3	3	3	3
139	149	121	185	164	145	172	205	239	242	3	3	3	3	3	3	3	3	3	3
181	149	149	181	190	114	117	124	158	152	3	3	3	3	3	3	3	3	3	3
146	139	147	170	148	104	88	112	150	136	3	3	3	3	3	3	3	3	3	3
147	136	112	118	129	139	120	121	195	377	3	3	3	3	3	1	1	1	1	1

Table 19: Dating of ***SARUM16*** (AD 1229-1338) against reference chronologies at AD 1338

Reference chronology	Spanning	Overlap	t-value
EXCATH1 *(Mills 1988)*	1137-1332	104	6.06
LONDON *(Tyers pers comm)*	413-1728	110	5.08
CL_QMF1 *(Tyers 1999b)*	1218-1328	100	4.77
WNTERBRN *(Miles and Worthington 2000)*	1177-1341	110	5.17
CRAWLEYC *(Tyers and Barefoot unpubl)*	1170-1338	110	5.13
THORNE *(Tyers et al 1997)*	1200-1319	91	5.32
WINDSOR *(Haddon-Reece et al 1990)*	1231-1354	108	5.41
WIMBORNE *(Miles 1994)*	1259-1634	80	5.89
GLAST *(Bridge 1983)*	1095-1334	106	5.93
NCADBRY1 *(Miles and Worthington 1998)*	1196-1285	57	6.33

Table 20: Matrix of *t* -values and overlaps for components of ***salc31***

Sample:	***salc31c***	***salc43***
Last ring date AD:	1668	1662
salc31ab	5.71 / 19	11.56 / 78
	salc31c	7.63 / 33

Table 21: Matrix of *t* -values and overlaps for components of ***SARUM17***

Sample:	***salc2932***
Last ring date AD:	1684
salc2831	5.17 / 100

Table 22: Ring-width data for site master curve

SARUM17 AD 1556-1684 Salisbury Cathedral - Timber support tower - English material 4-timber / 2-tree mean

129 rings, starting date AD 1556

ring widths (0.01mm)										**number of samples in master**									
155	241	401	386	396	335	478	297	363	375	1	1	1	1	1	1	1	1	1	1
250	400	326	274	233	241	218	255	325	221	1	1	1	2	2	2	2	2	2	2
188	210	197	210	263	234	217	255	213	269	2	2	2	2	2	2	2	2	2	2
195	168	161	184	114	140	135	185	177	153	2	2	2	2	2	2	2	2	2	2
182	208	167	128	152	145	146	137	145	152	2	2	2	2	2	2	2	2	2	2
193	178	182	195	177	125	123	191	145	168	2	2	2	2	2	2	2	2	2	2
157	185	164	123	133	135	128	135	120	200	2	2	2	2	2	2	2	2	2	2
194	156	179	200	151	130	137	129	96	112	2	2	2	2	2	2	2	2	2	2
125	144	161	178	186	170	115	143	110	128	2	2	2	2	2	2	2	2	2	2
146	164	194	114	145	142	119	110	127	151	2	2	2	2	2	2	2	2	2	2
129	137	142	100	143	160	149	136	127	153	2	2	2	2	2	2	2	2	2	2
135	131	174	149	136	121	122	155	118	106	2	2	2	1	1	1	1	1	1	1
108	156	153	80	63	63	59	71	99		1	1	1	1	1	1	1	1	1	

Table 23: Dating of ***SARUM17*** (AD 1556-1684) against reference chronologies at AD 1684

Reference chronology	Spanning	Overlap	t-value
SARUM6 *(Miles and Worthington 2000; Miles 2002a)*	1604-1668	65	5.23
SARUMBP7 *(Miles and Worthington 2000)*	1562-1661	100	5.44
CHAWTON *(Oxford unpubl)*	1289-1772	129	5.74
WILBURY2 *(Miles and Worthington 1999)*	1581-1657	77	5.74
MDM23 *(Miles et al 2003)*	1527-1618	63	5.88
OXON93 *(Haddon-Reece et al 1993)*	632-1987	129	5.96
SENG98 *(Bridge 1998a)*	944-1790	129	5.98
NEWDIG2 *(Bridge 1998b)*	1492-1639	84	6.30
HANTS02 *(Miles 2003)*	443-1972	129	6.58
SARUM5 *(Miles and Worthington 2000; Miles 2002a)*	1558-1662	105	6.76

Table 24: Matrix of *t* -values and overlaps for components of ***salc4552***

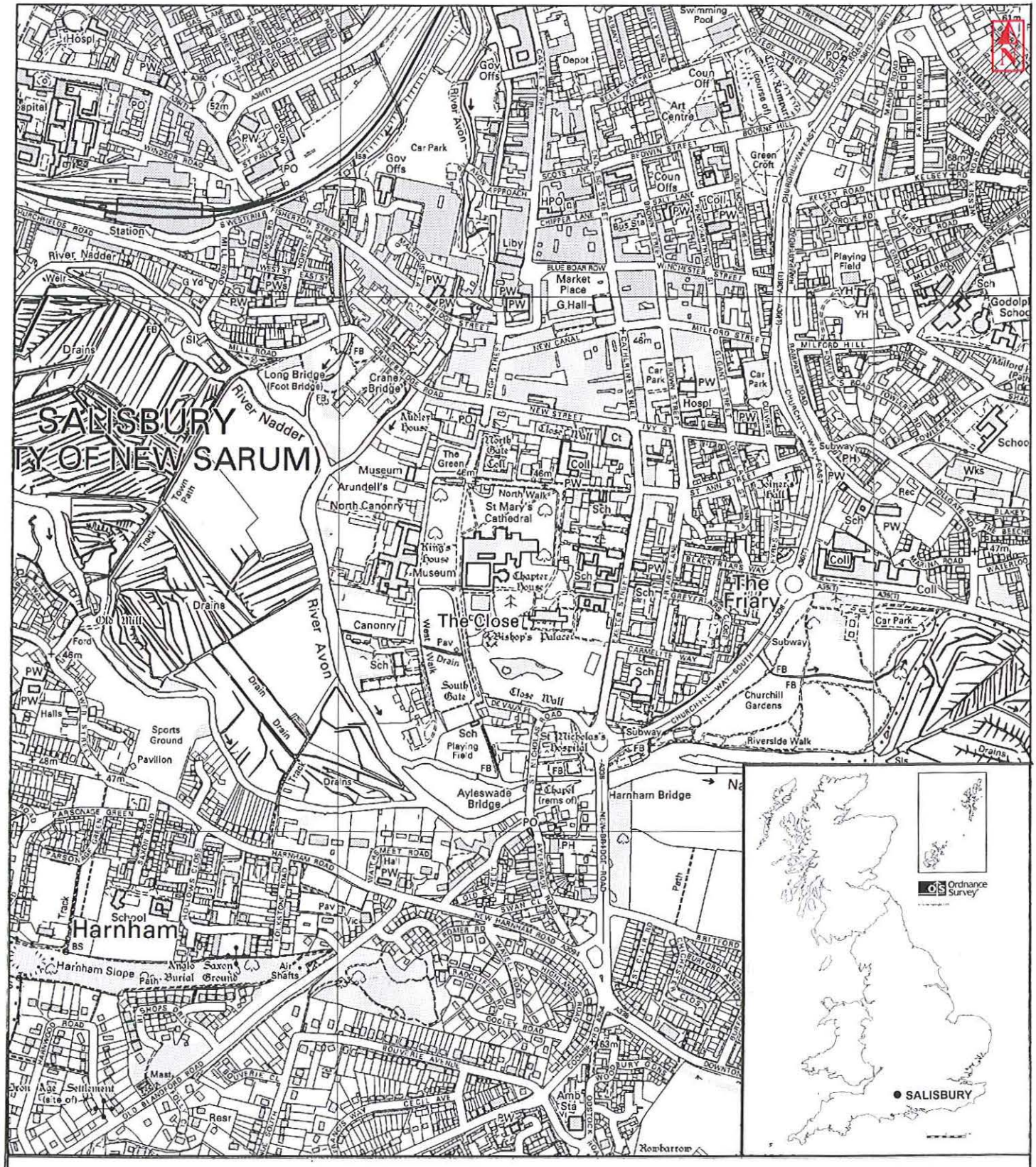
Sample:	***salc49***	***salc51***	***salc52***
Last ring date AD:	1675	1667	1679
salc45	3.83 / 45	5.55 / 40	2.87 / 45
	salc49	5.76 / 61	3.47 / 62
		salc51	5.78 / 54

Table 25: Chronicle of damage and repairs to the spire and tower of Salisbury Cathedral

THE BISHOP AND CHAPTER OF SALISBURY. Signification that their church, by the devotion of kings and nobles, has been sumptuously constructed by builders and architects of repute, but by reason of the faulty foundation, which was laid in a marshy spot, the walls and tower are threatened with ruin, and that since January 1361 (ie 1362) there have been unwonted hurricanes in England, so that the building is riven, and the bell tower for the most part fallen; they therefore pray for the appropriation of the church of St Thomas, value £ 10 of the bishop's collation, that they may be able to spend its fruits on the fabric of the cathedral.
(Cal. Papal Registers: Petitions 1[1342-1419], 462)

Granted for six years from the next voidance of the said church. (Avignon, 6 Non. Oct. 1363) TO THE CHAPTER OF SALISBURY. Appropriation for six years of the church of St Thomas, Salisbury, value £10 in the patronage of Bishop Robert, a vicar's portion being assigned. The proceeds are to be applied to the repair of the walls and bell tower, damaged by recent storms.
(Cal. Papal Registers: Papal Letters IV [1362-1404], 89)

LICENCE FOR THE DEAN AND CHAPTER OF THE CATHEDRAL CHURCH OF SALISBURY to acquire in mortmain £20 yearly of land and rent, not held of the king, in aid of the maintenance of the works of the said cathedral.
(cat. Patent Rolls: 3 Sept. 1366)



Print Scale: 1:10000

Printed by: j1fullar

Print date: 15 April 2004

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ENGLISH HERITAGE

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Figure 1: Plan of Salisbury with inset map of the United Kingdom

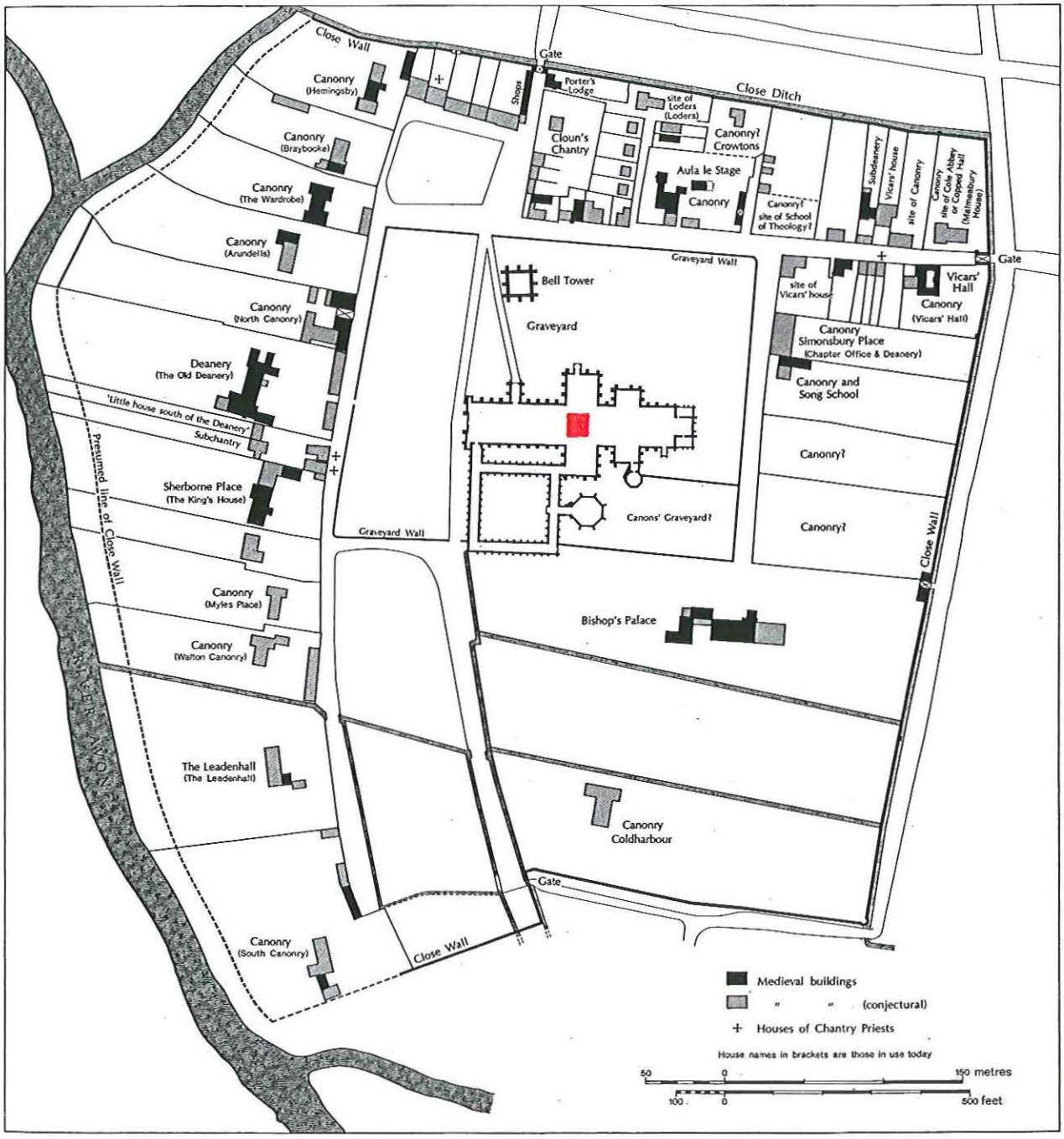


Figure 2: Reconstructed plan of the close in the late medieval period (RCHME 1993)

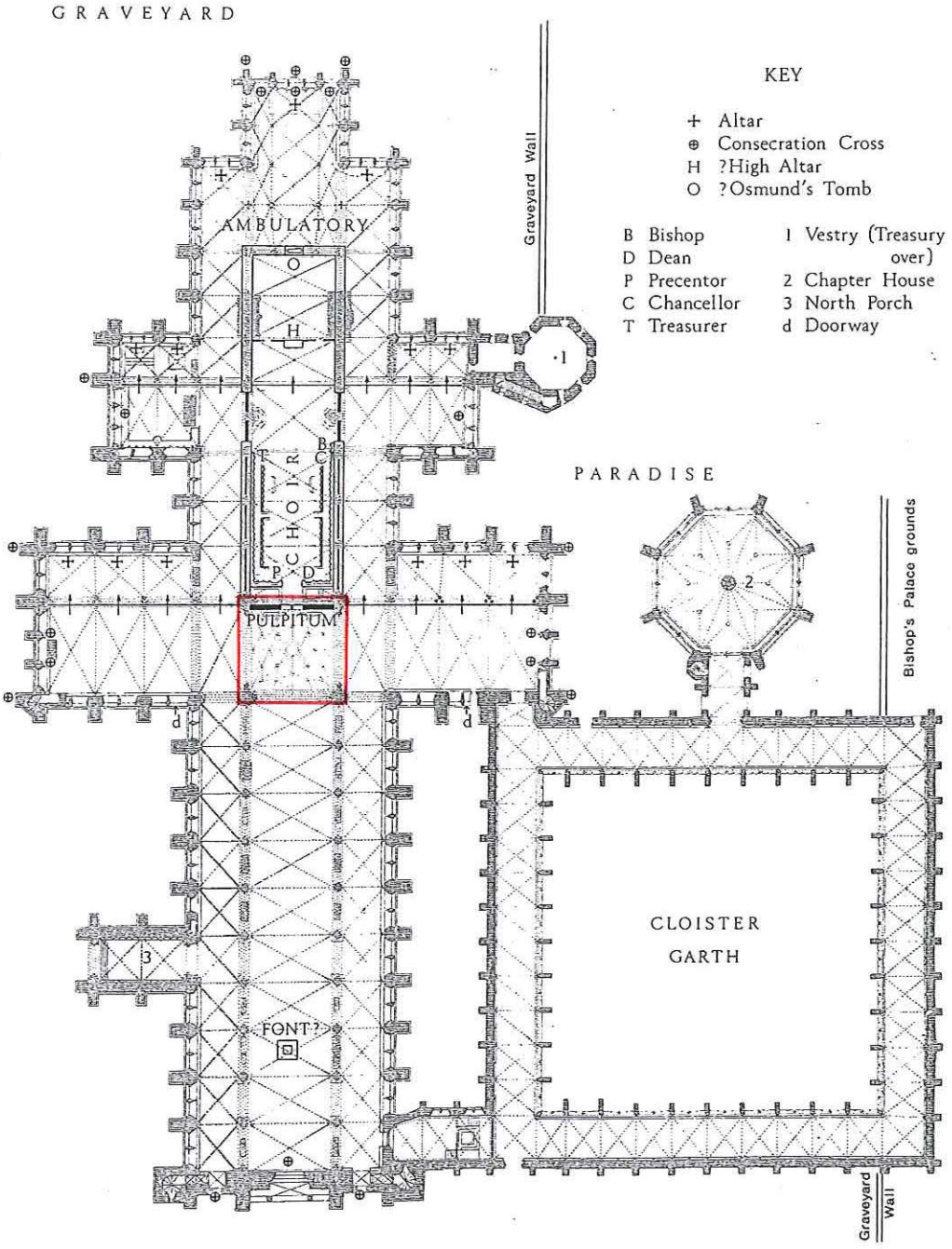


Figure 3: Plan of Salisbury Cathedral showing areas sampled (after Cocke and Kidson 1993)

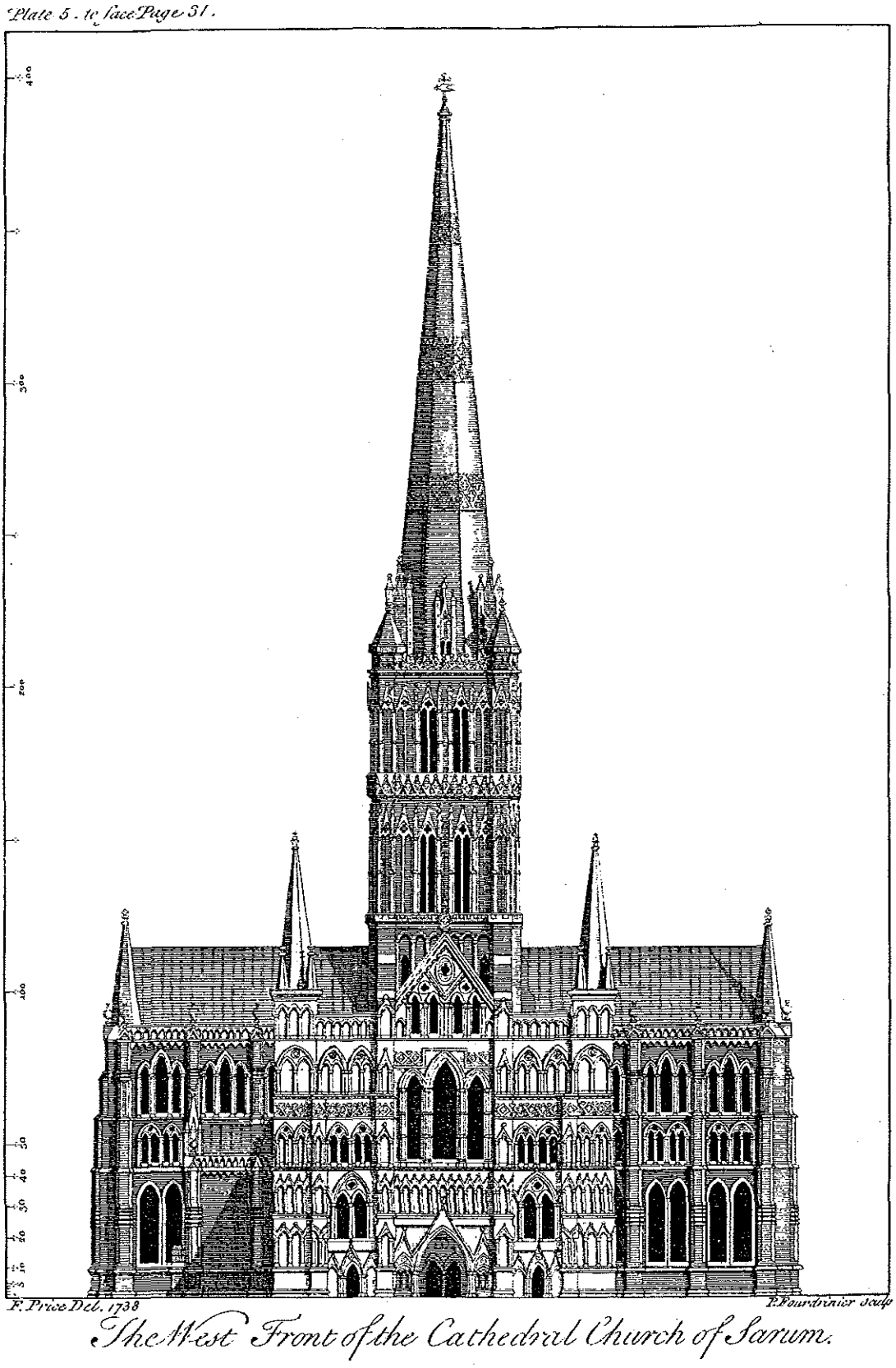


Figure 4: West front of Salisbury Cathedral showing tower and spire (Price 1753, plate 5)

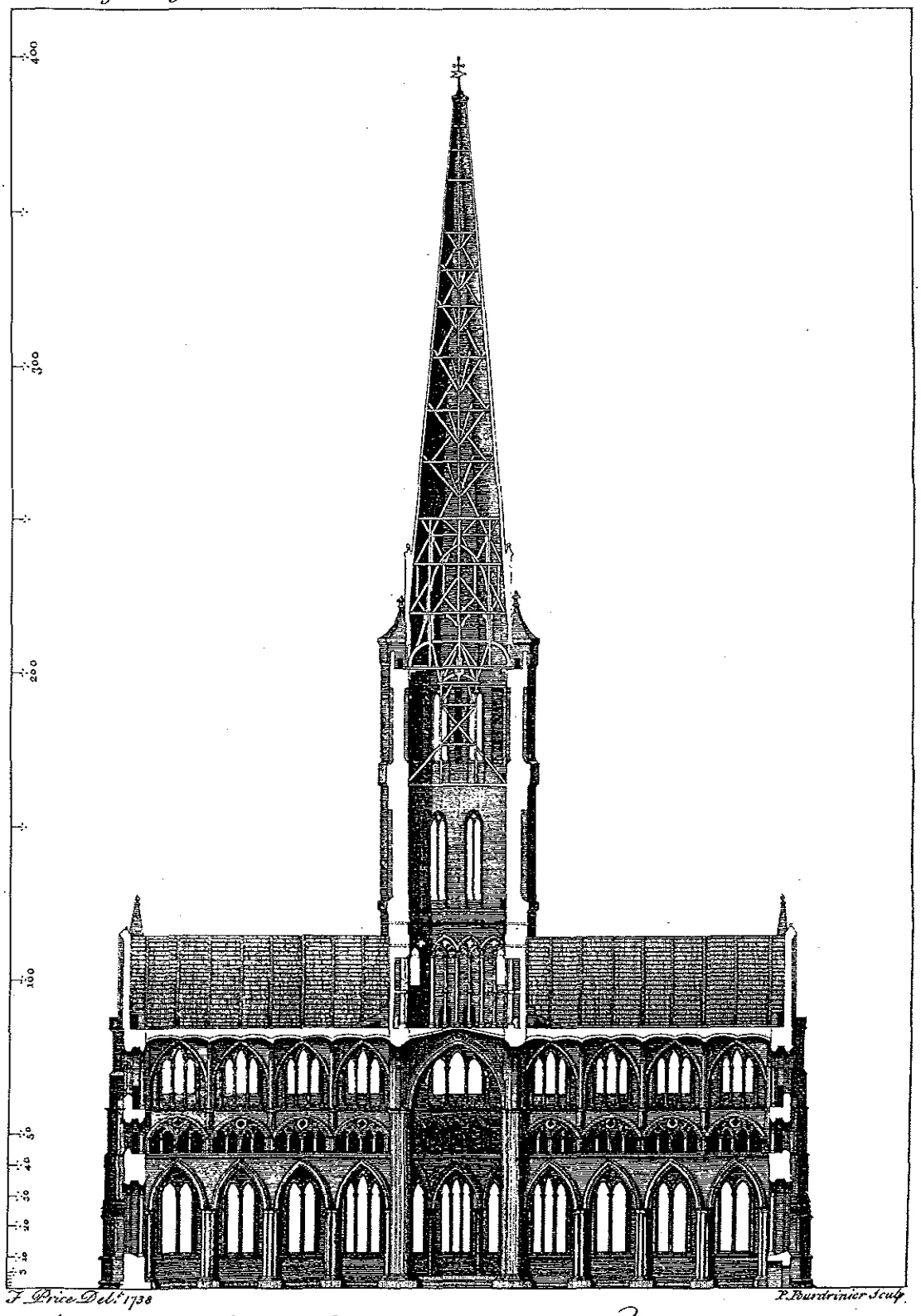


Figure 5: Transverse section of tower and spire of Salisbury Cathedral (Price 1753, plate 6)

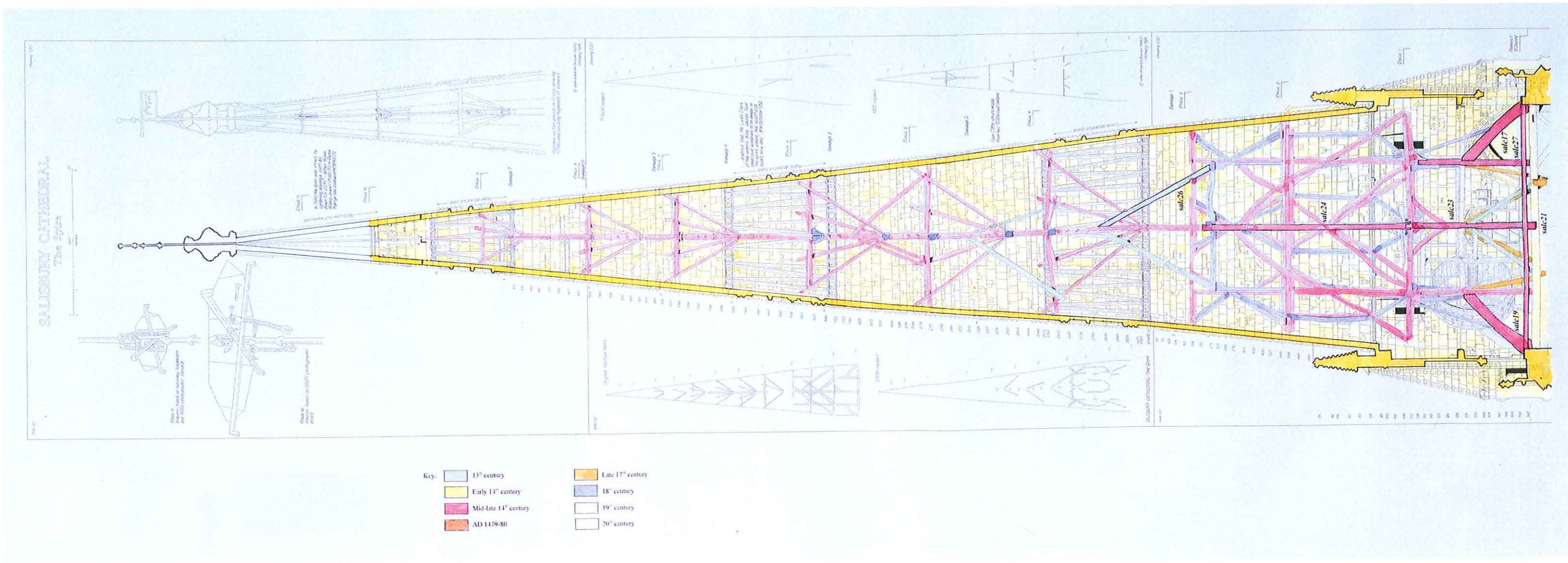


Figure 6: Section of spire looking north showing phasing and locations of timbers sampled – scale 1:80 (after J Atherton)

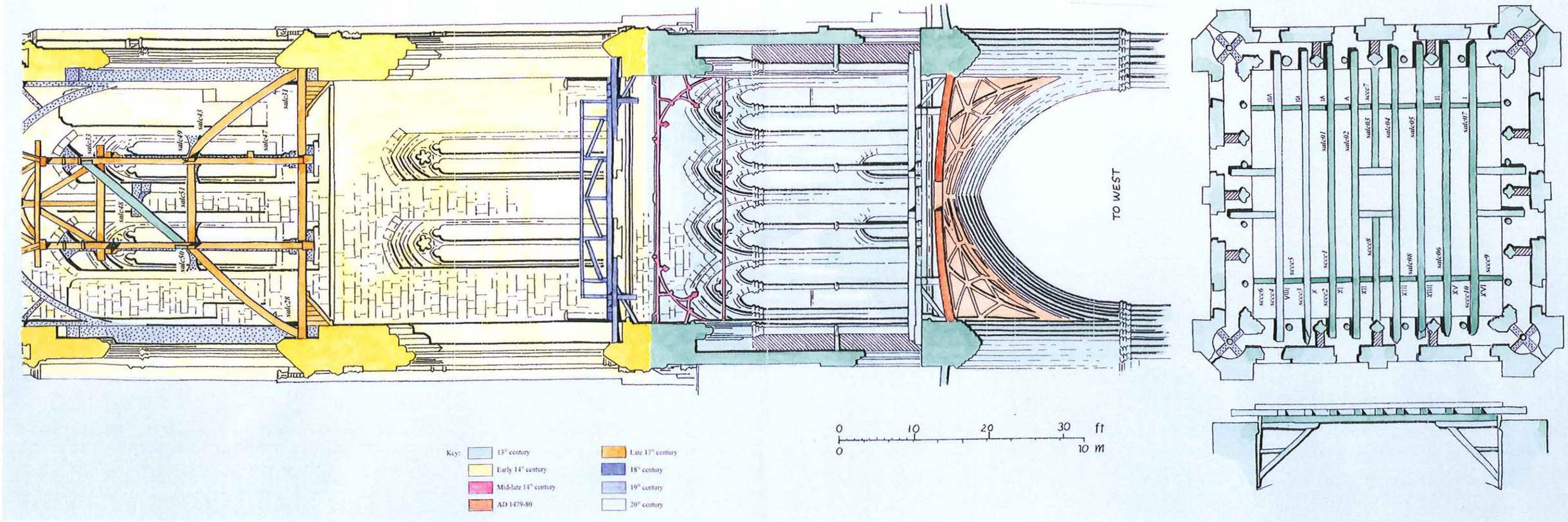
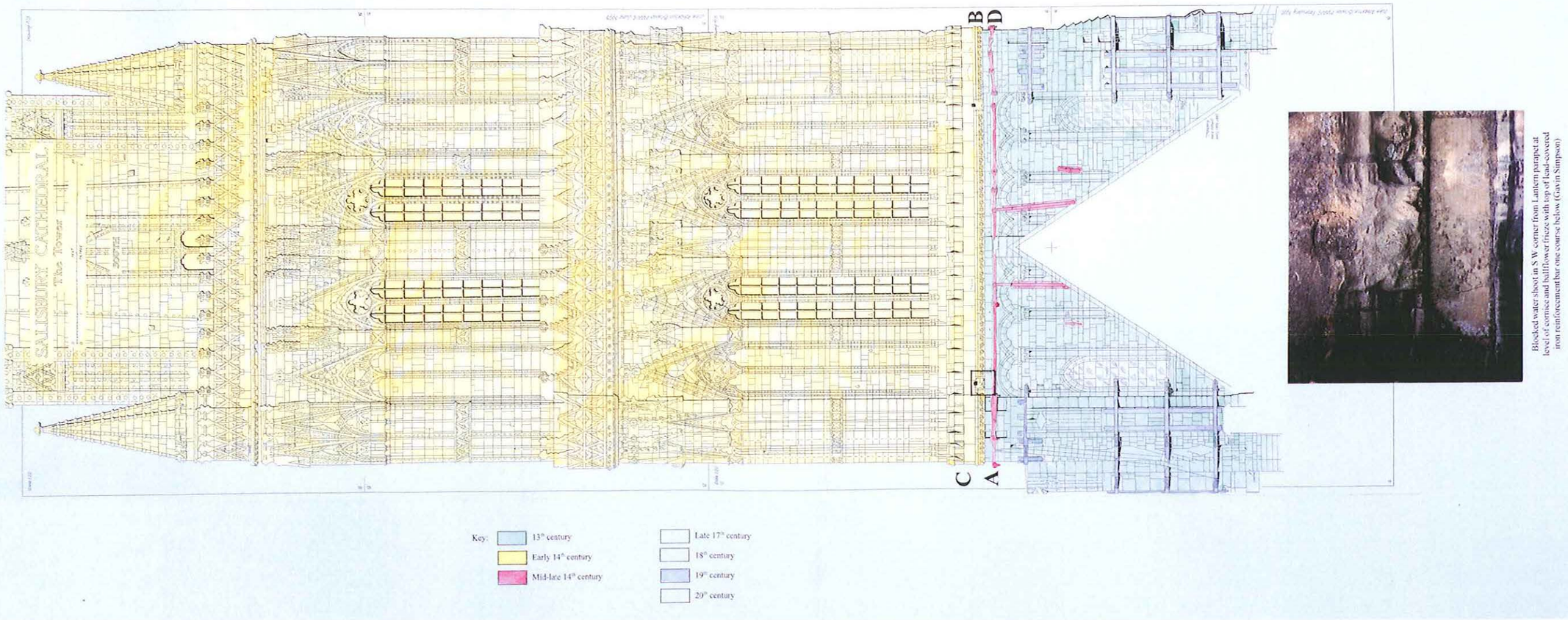


Figure 7: Section of upper part of tower looking west, plan at tower base, and section of clock tower chamber floor looking east, showing phasing and locations of timbers sampled – scale 1:80 (after J Atherton)



Blocked water shoot in S W corner from Lantern parapet at level of cornice and ballflower frieze with top of lead-covered iron reinforcement bar one course below (Gavin Simpson)

Figure 8: South elevation of tower showing phasing - scale 1:80 (after J Atherton)

Detail **A** showing course containing lead plugs, **B** showing last course of Simon of Ghent's work ball-flower decoration and rainwater spouts (detailed on inset), **C** showing the first course of Roger de Martival's work after AD 1315, and **D** showing late thirteenth-century iron reinforcement (after J Atherton)

Figure 9: St Mary's Church, Long Sutton, Lincolnshire. © Crown copyright. NMR. BB69/7077

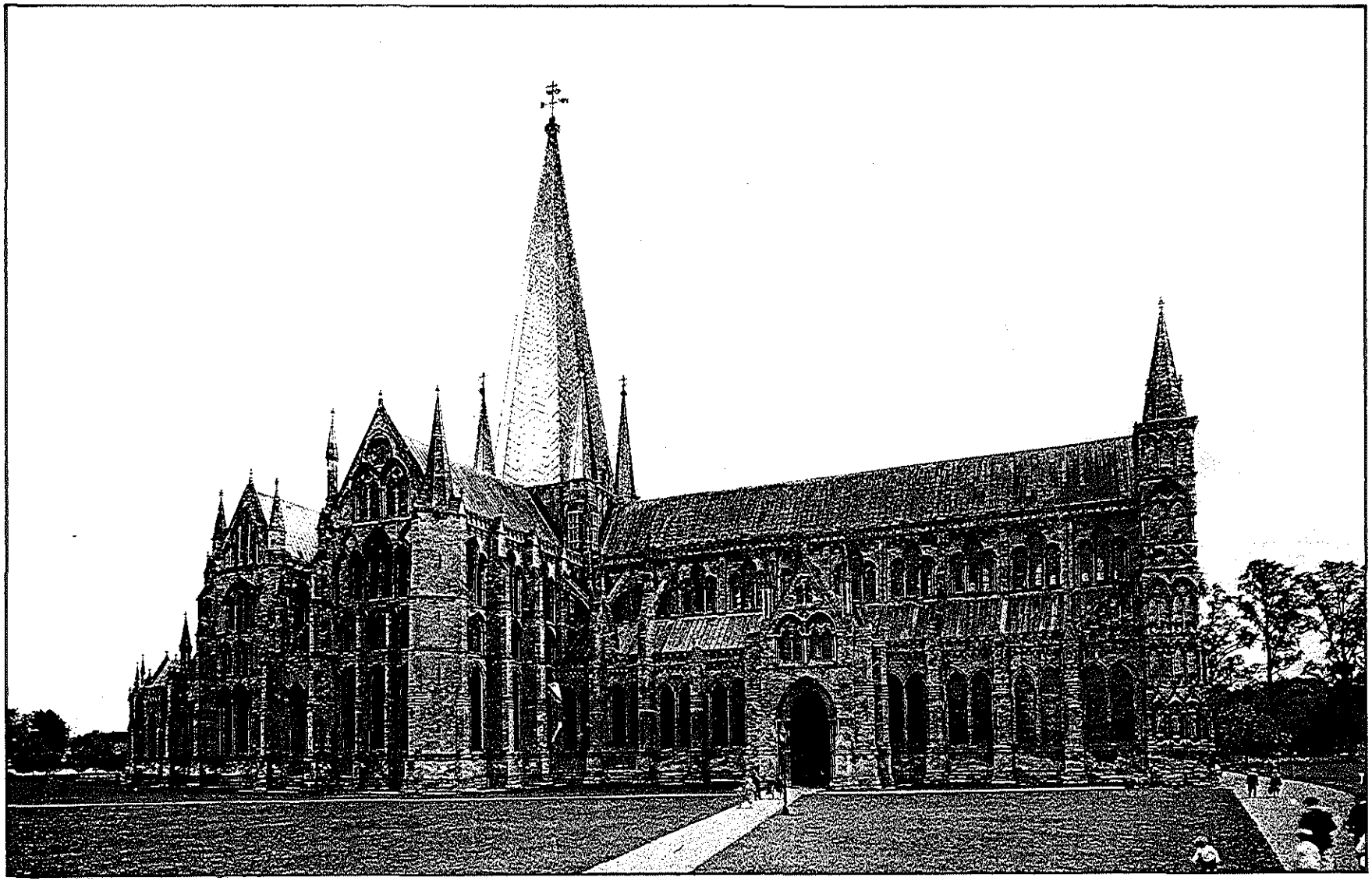


Figure 10: Conjectural reconstruction of Salisbury Cathedral at the end of the thirteenth century (Simpson unpubl)

Figure 11: Seal of Bishop Walter de la Wyle (AD 1263-71) with enlarged detail from the bottom of seal presumably showing a stylistic depiction of the Cathedral with a short spire (Society of Antiquaries Collection, C26)

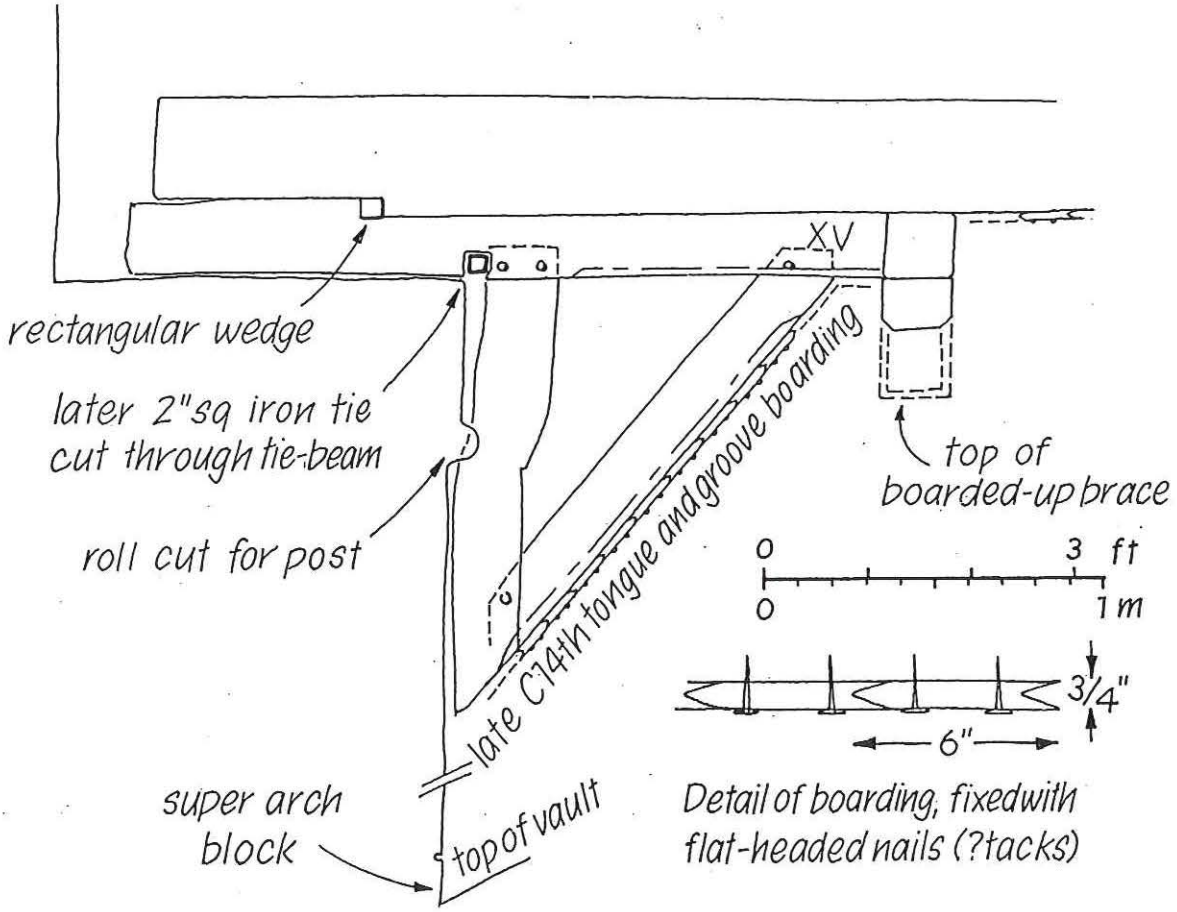


Figure 12: Detail of saddle bracket and boarding (after J Atherton). Full size section of typical imported V-edged Baltic oak ceiling board

Figure 13: Remains of Baltic oak ceiling board to clock chamber floor. © Crown copyright. NMR. BB73/3163

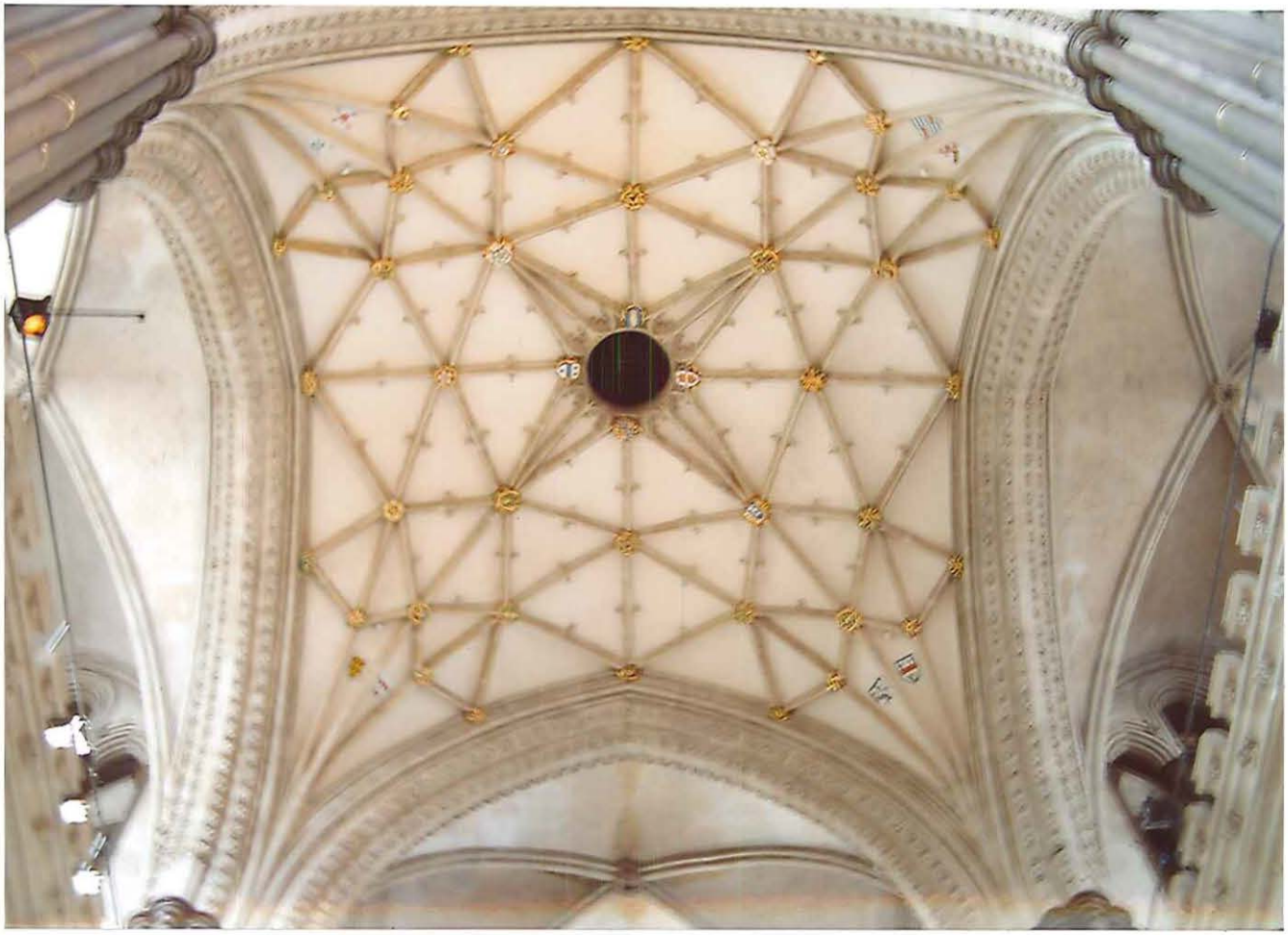


Figure 14: View of great crossing vault of AD 1479 from below (Dr P Marshall)

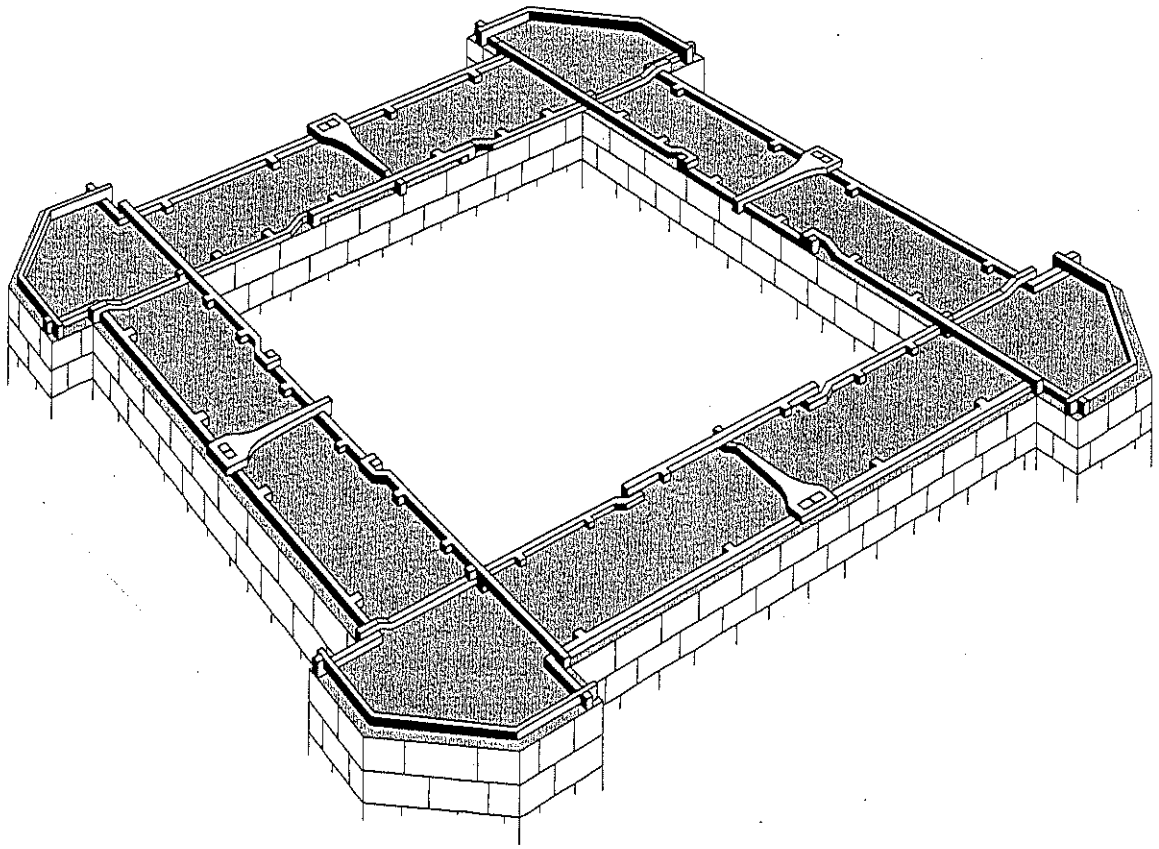


Figure 15: Early fourteenth-century iron reinforcement at the top of the tower (after a drawing by J A Reeves) (Cocke and Kidson 1993, fig 5)

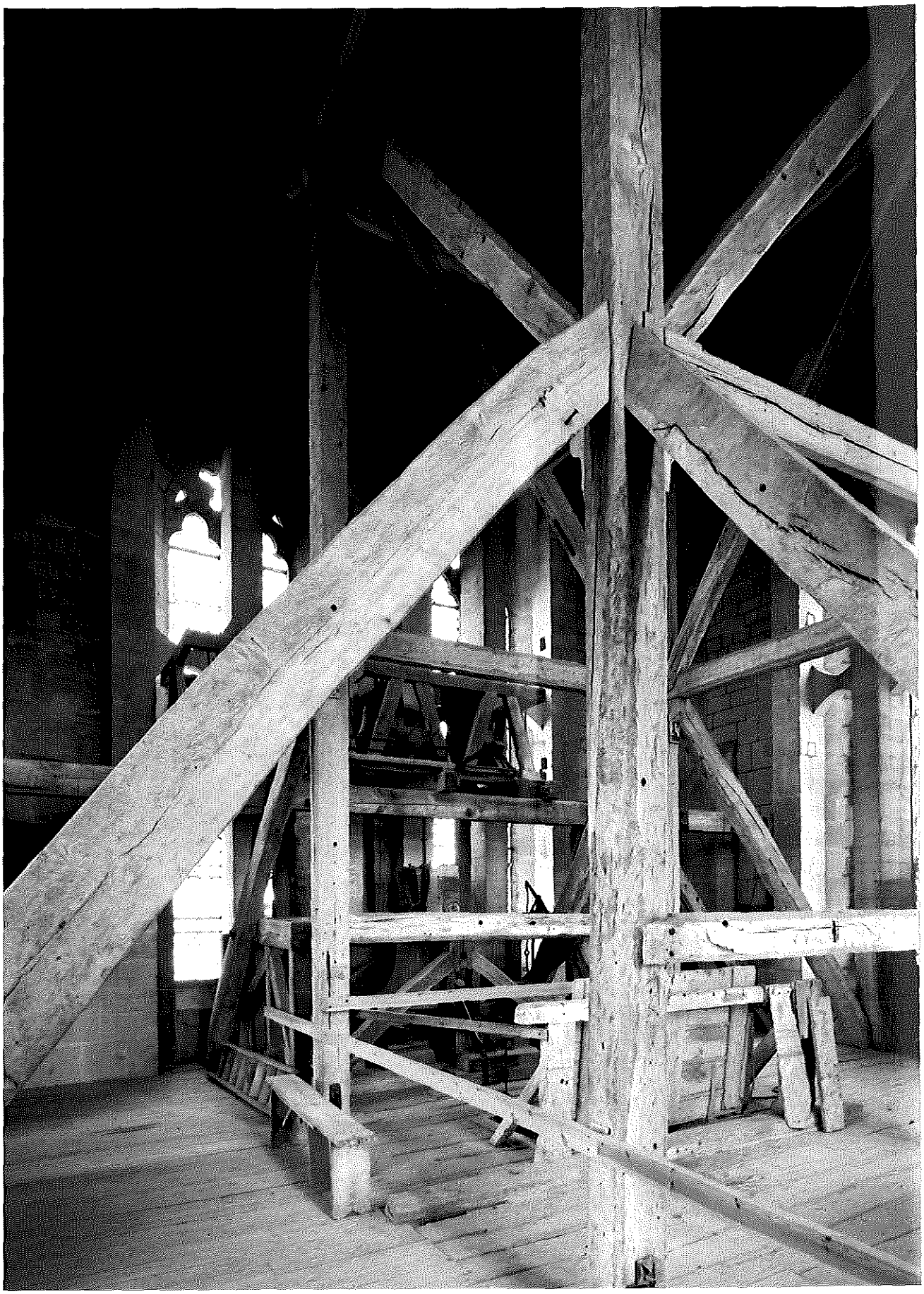


Figure 16: Lower part of timber tower in bell chamber from the south-west. © Crown copyright. NMR. BB71/2461

Figure 17: Junction of lower rails, reused timber braces and south-west corner post to Bell Chamber (Dr P Marshall)

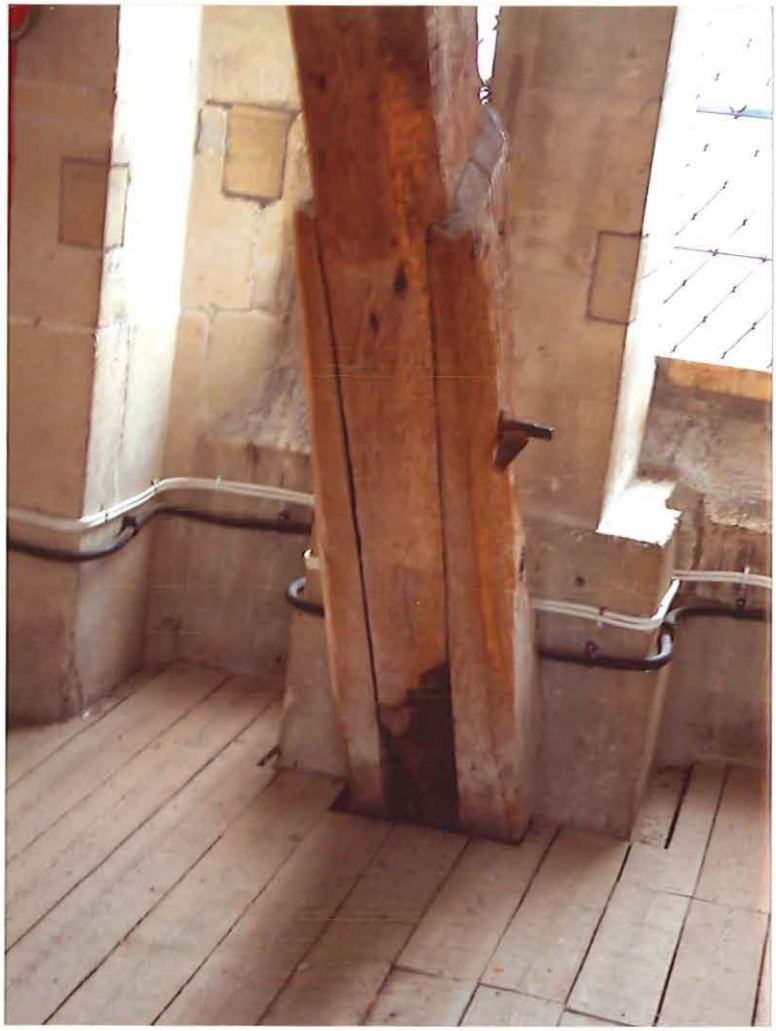


Figure 18: West brace to south-west corner of timber tower, bell chamber, showing cleats added to strengthen area damaged by AD 1741 fire (Dr P Marshall)

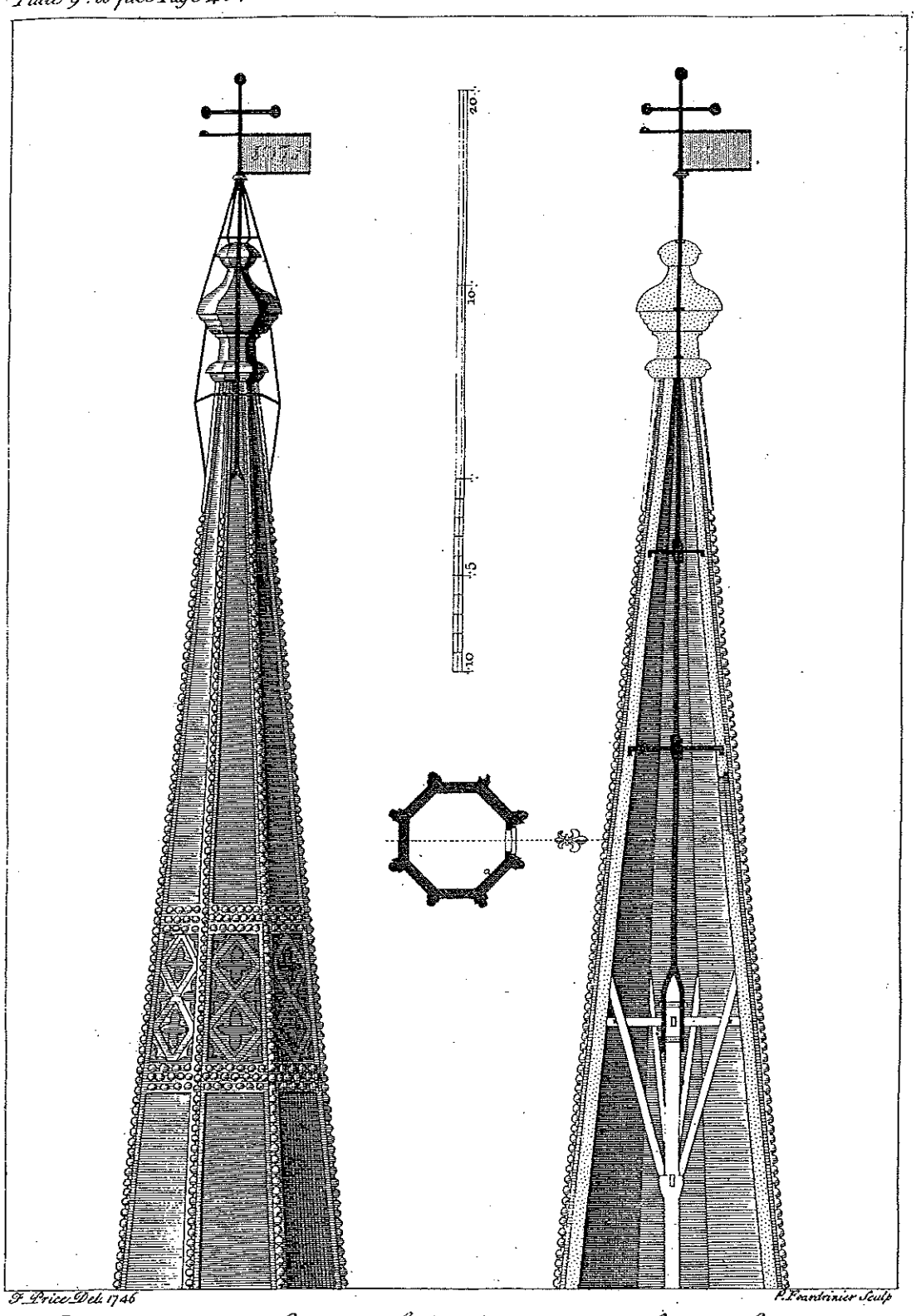


Figure 19: Elevation and section of top of spire (Price 1753, plate 9)

Figure 20: Base of spire at Eight Doors level showing the great wheel. © Crown copyright. NMR. BB71/2462

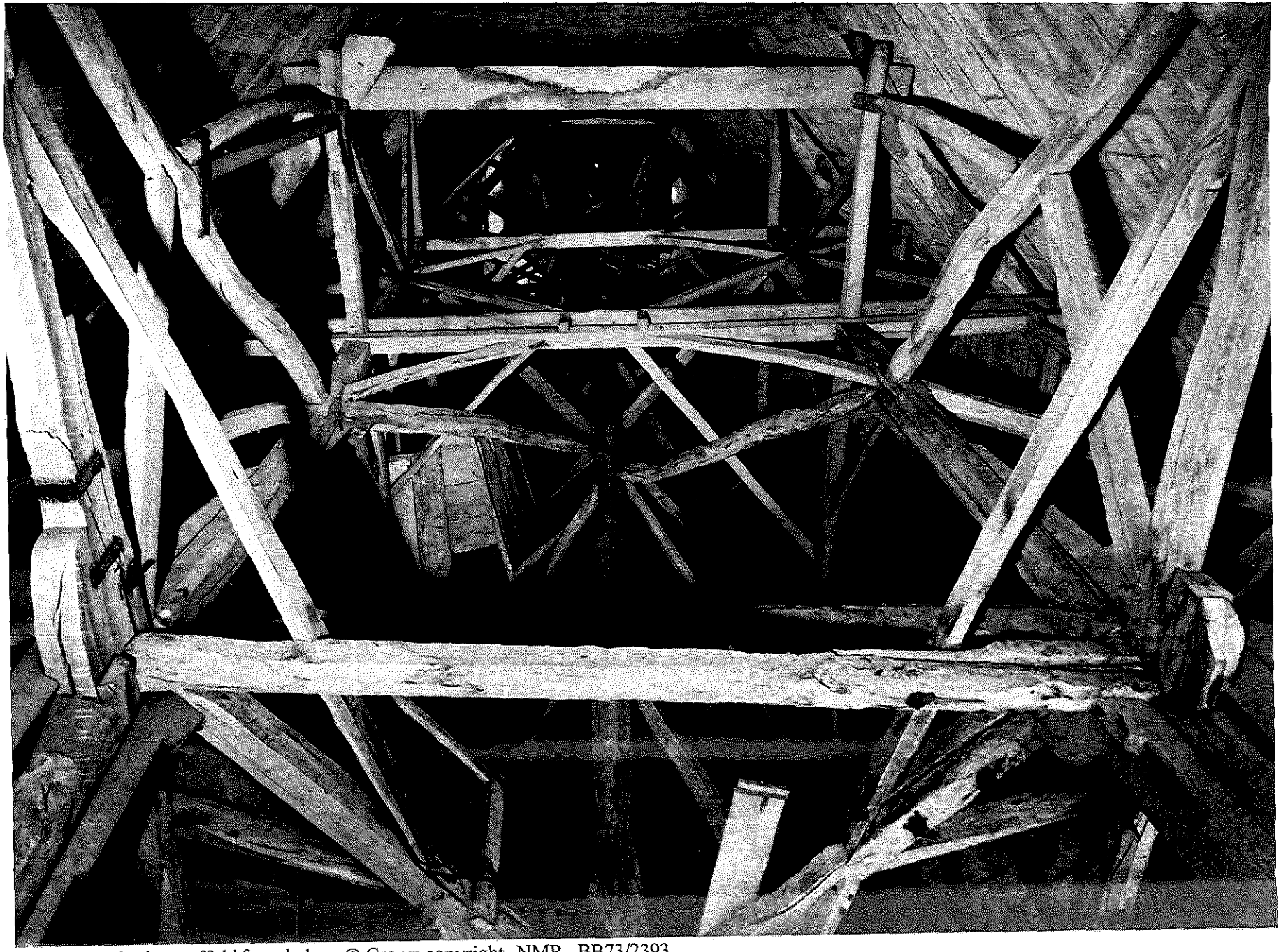
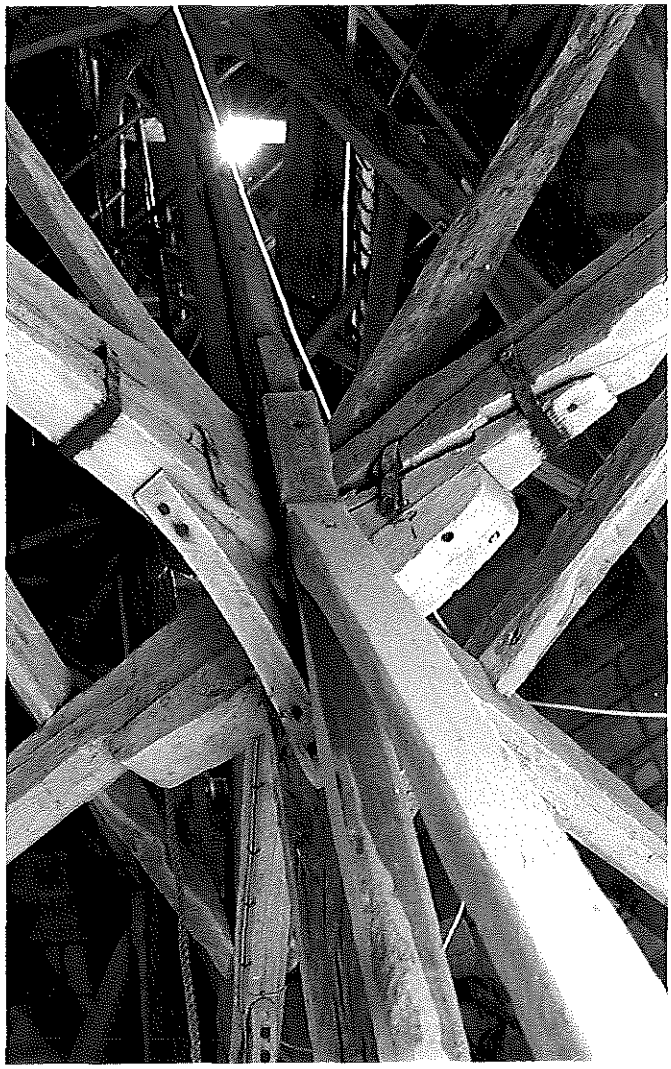


Figure 21: View of spire scaffold from below. © Crown copyright. NMR. BB73/2393

Figure 22: Views of spire scaffold from below (Dr P Marshall)



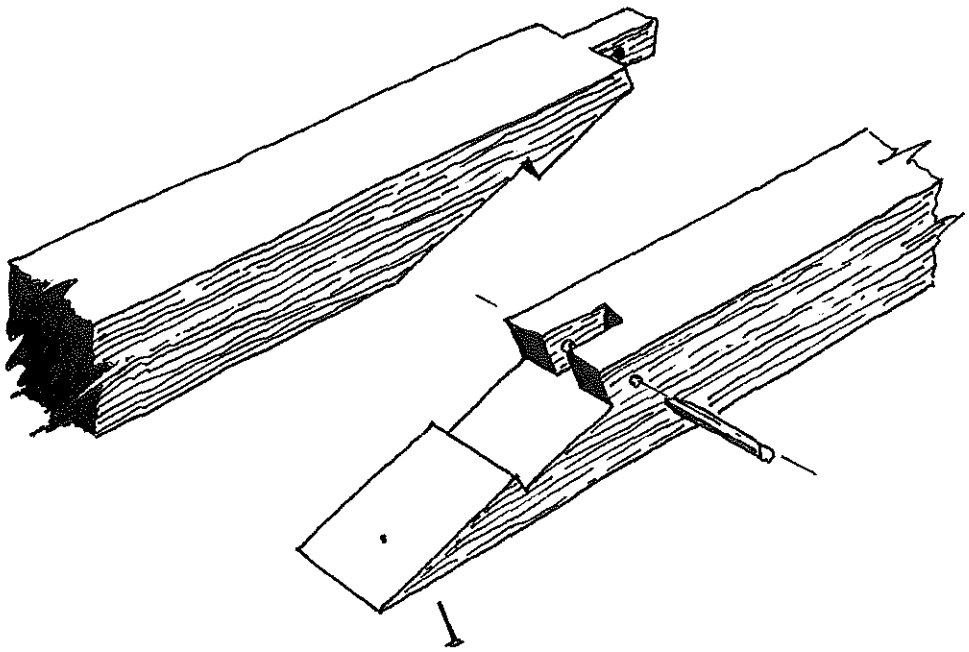


Figure 23: East corner post from east showing intersection of timbers at Stage 1 (Dr C R Salisbury), and detail of scarf joint

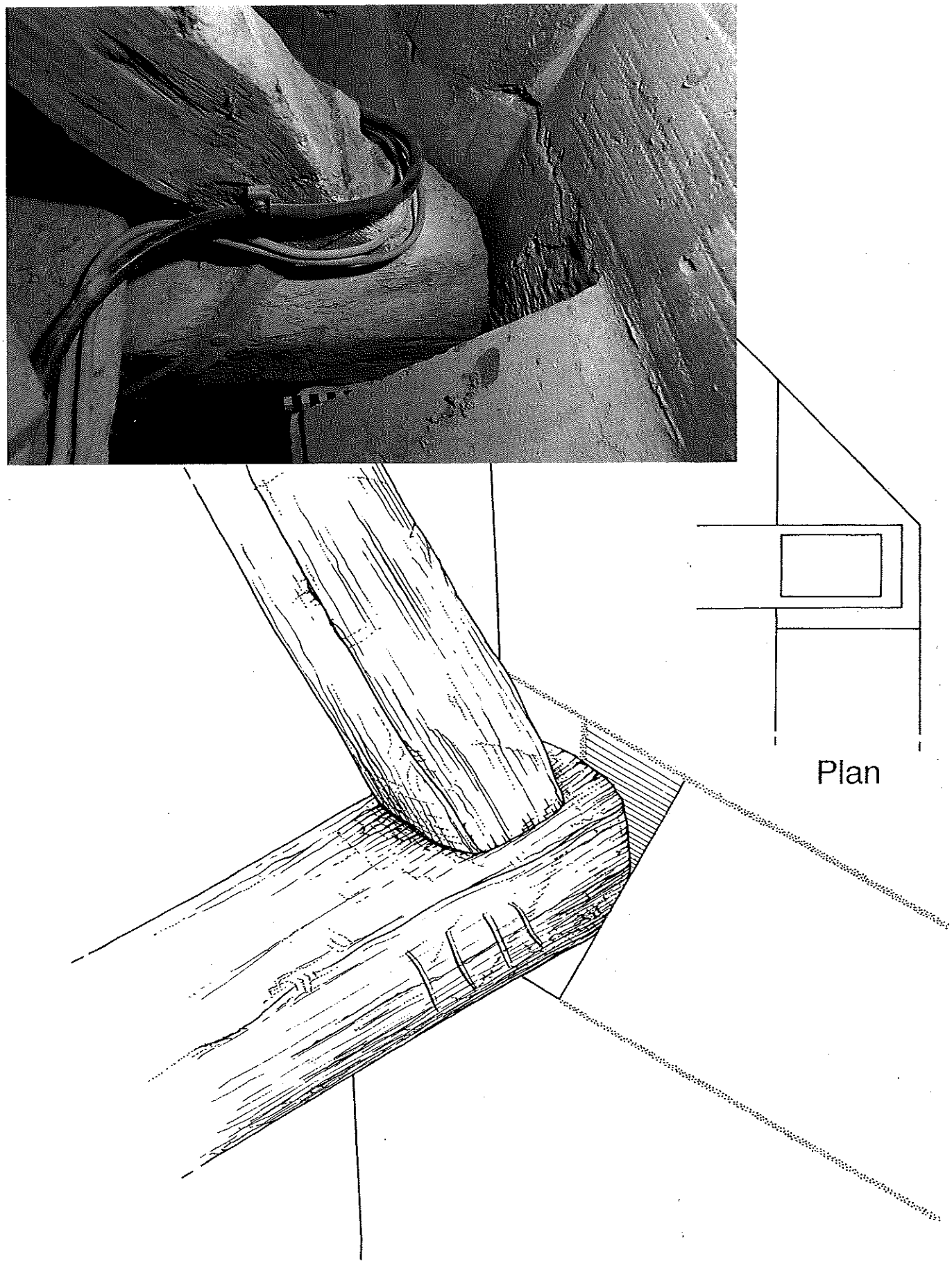


Figure 24: North end of extension to south-west to north-east rail at Stage 1 where it meets the north-east angle of the spire octagon, showing the cutting back into the masonry as well as reinforcement strap of iron and original carpenter's mark (Dr C R Salisbury), and detail of joint (J Goddard)

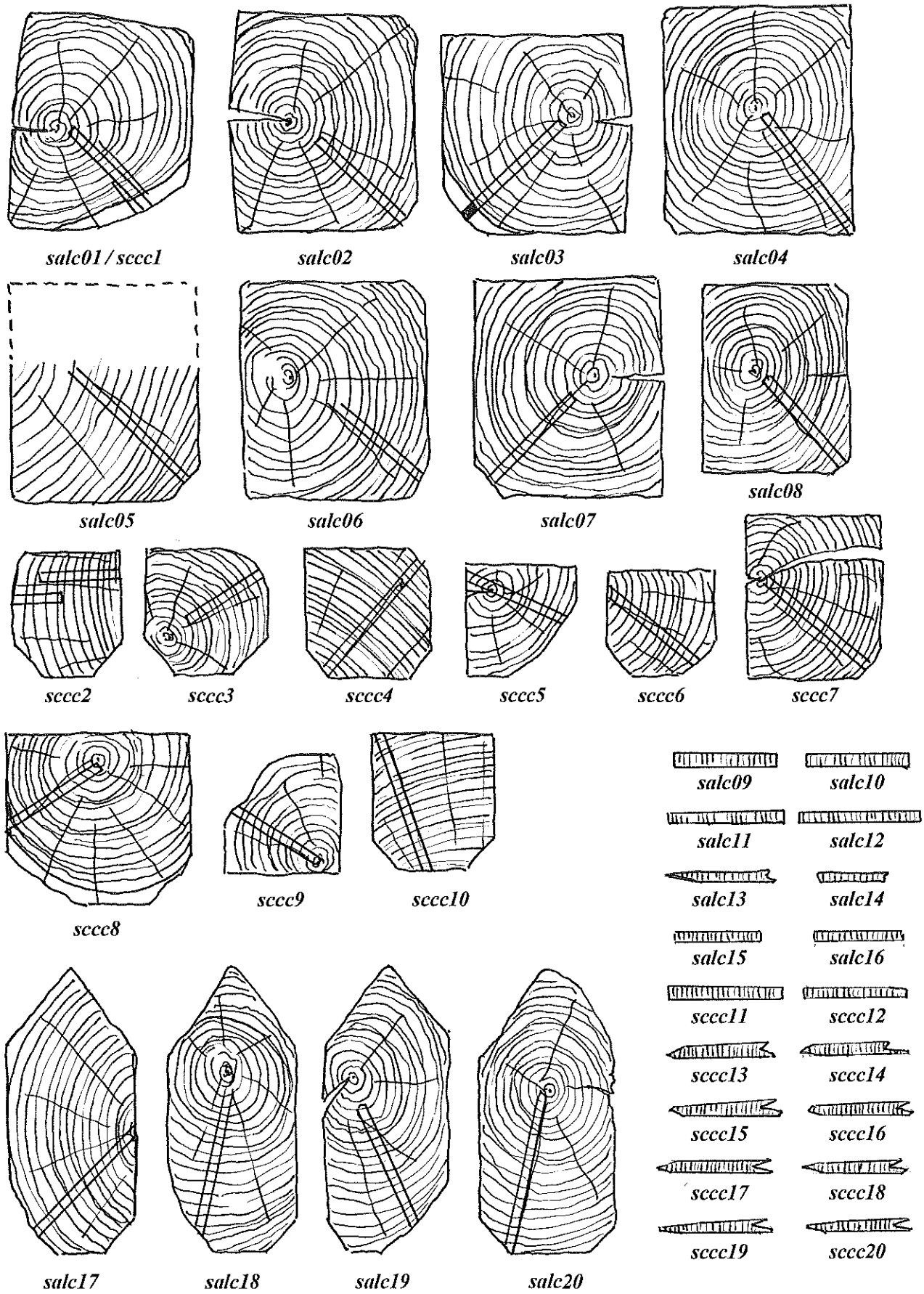


Figure 25: Scale section drawings of timbers sampled (scale 1:8)

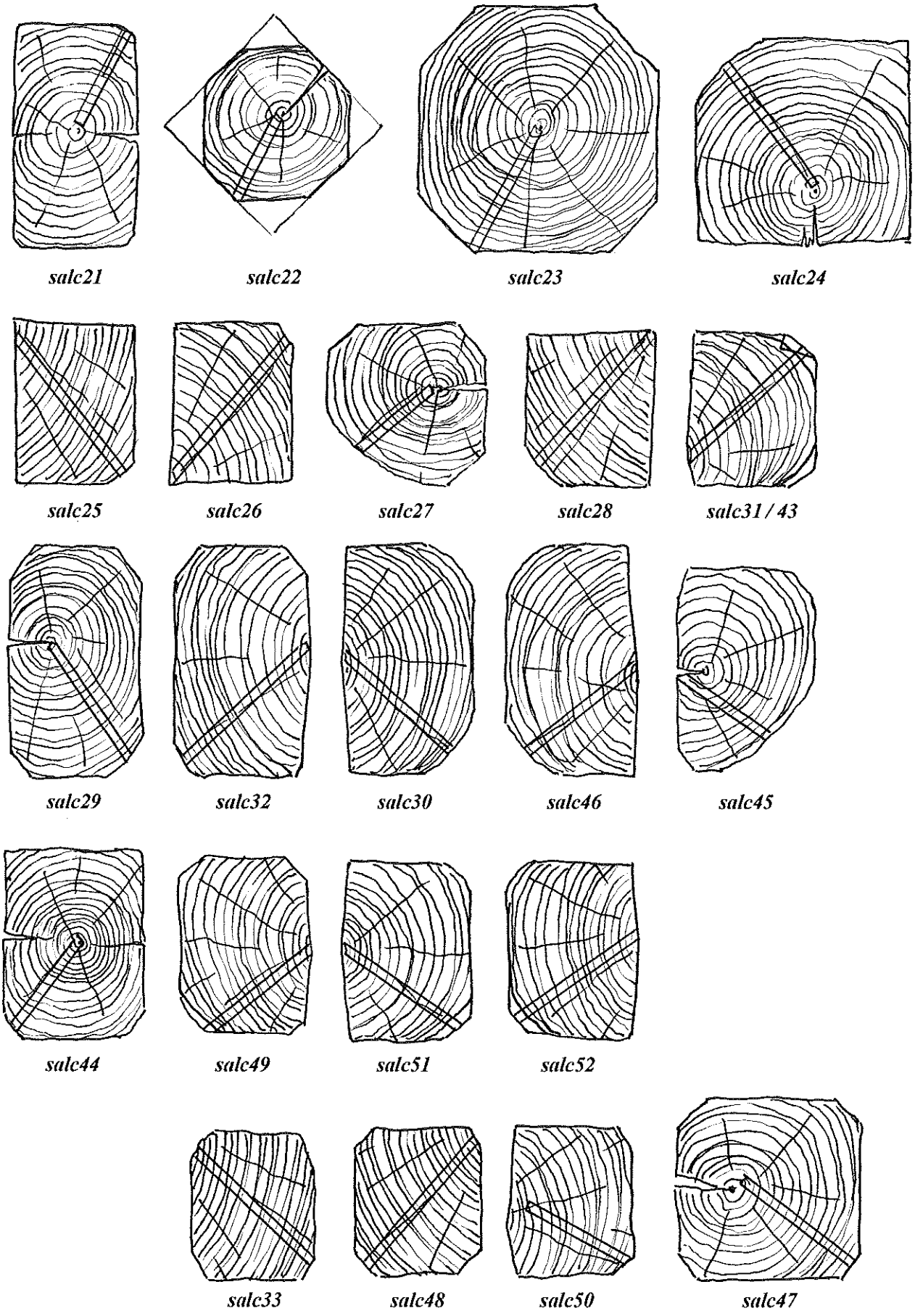


Figure 25 (cont): Scale section drawings of timbers sampled (scale 1:8)

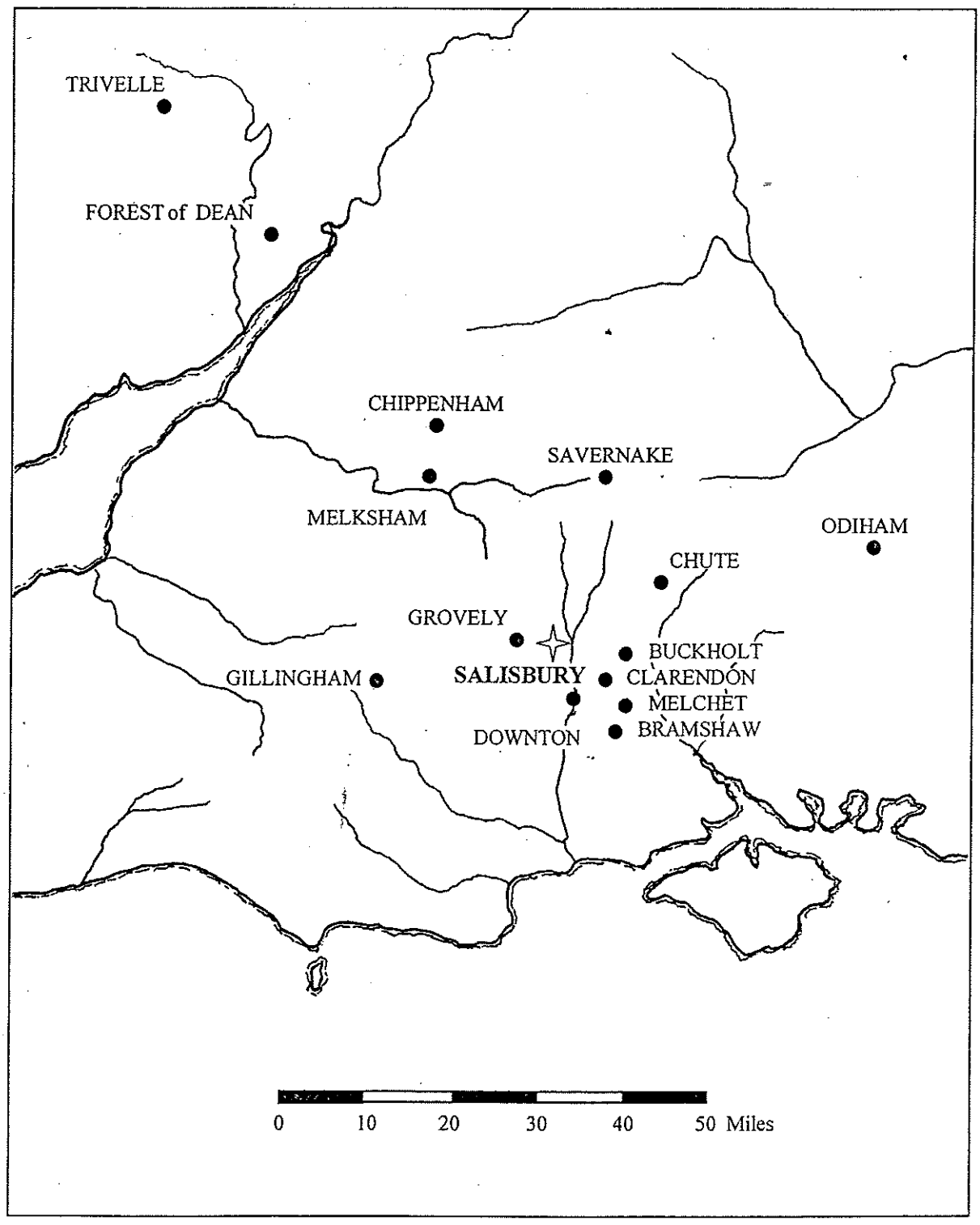


Figure 26: Map of south-west England showing location of woods and forests used in the construction of the Cathedral (after Simpson 1996)

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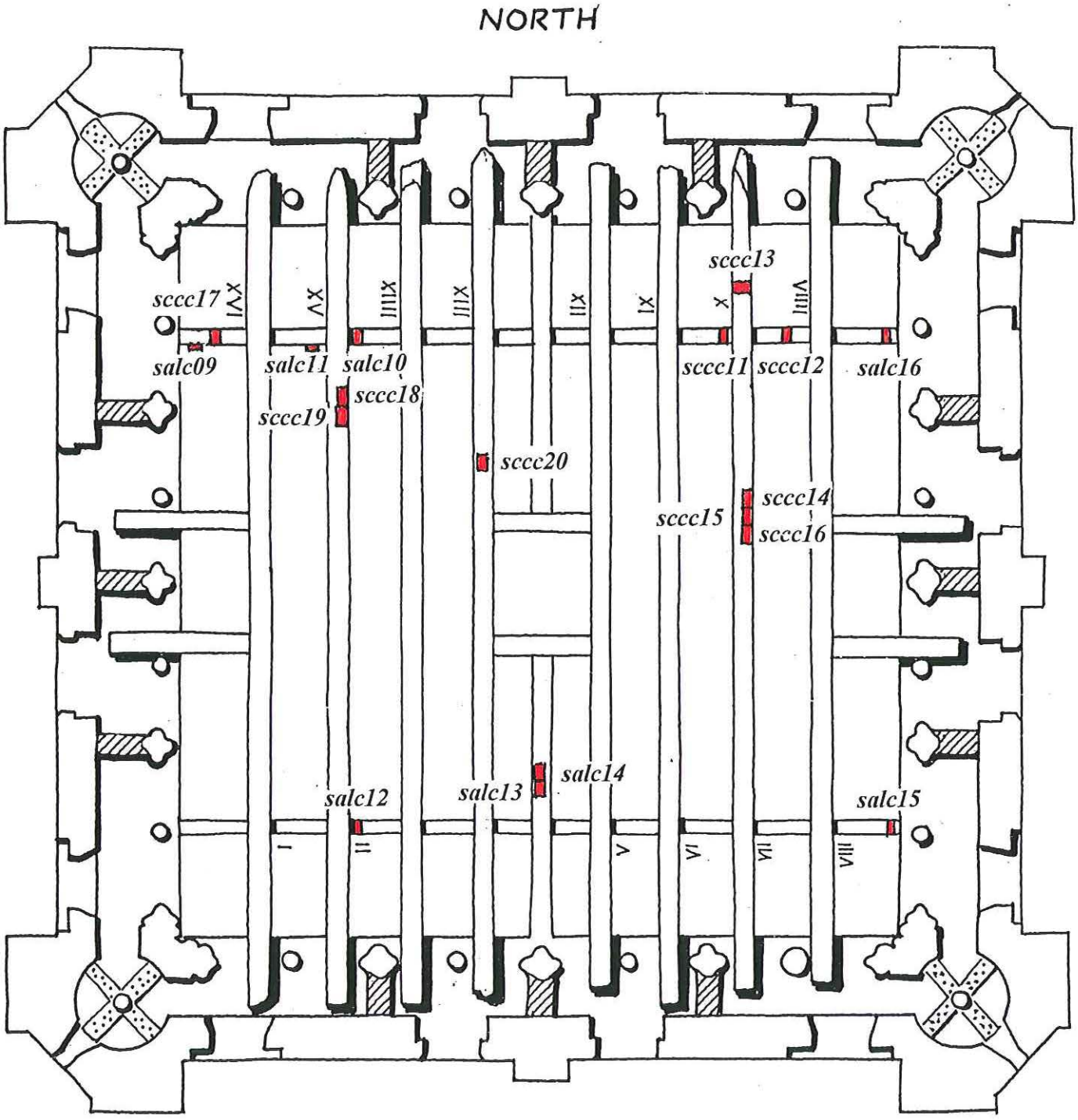

Figure 27: Plan of Clock Chamber floor with Baltic board samples superimposed (after J Atherton)